QC
801
.U55
no.15

TN-59-256
Document No. AD-212265

GRD RESEARCH NOTES

No. 15

PROCEEDINGS OF THE FIRST ANNUAL ARCTIC PLANNING SESSION, NOVEMBER 1958

Edited by
J. H. Hartshorn

April 1959

GEOPHYSICS RESEARCH DIRECTORATE
AIR FORCE CAMBRIDGE RESEARCH CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS

lesearch Notes are published
ium for disseminating, in a
rapid and informal way,
research results obtained
se of a broader investigation,
information pending comple-
ajor research effort."

105 003

Requests for
Department o
government ag

Armed Service
Arlington Hall
Arlington 12, V

Department of
for ASTIA ser
fied by the co
or contract.

All other perso

U. S. DEPART
OFFICE OF TE
WASHINGTON 2

AFCRC-TN-59-256
ASTIA Document No. AD 212265

U.S. Air Force, Cambridge Research Center, Geophysics
" Research Directorate

GRD Research Notes
No. 15

PROCEEDINGS OF THE FIRST ANNUAL ARCTIC PLANNING SESSION, NOVEMBER 1958

edited by
J. H. Hartshorn

QC
801
.U55
no. 15

April 1959

LIBRARY
JUL 30 1959
WEATHER BUREAU

Terrestrial Sciences Laboratory
GEOPHYSICS RESEARCH DIRECTORATE
U.S. AIR FORCE, CAMBRIDGE RESEARCH CENTER, Geophysics Research Directorate
" AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
Bedford, Mass.

105 009

National Oceanic and Atmospheric Administration

International Polar Year (IPY) 2007-2008

ERRATA NOTICE

One or more conditions of the original document may affect the quality of the image, such as:

Discolored pages
Faded or light ink
Binding intrudes into the text

This has been a co-operative project between the NOAA Central Library and the Climate Database Modernization Program, National Climate Data Center (NCDC). To view the original document contact the NOAA Central Library in Silver Spring, MD at (301) 713-2607 x124 or Library.Reference@noaa.gov.

HOV Services
12200 Kiln Court
Beltsville, MD 20704-1387
August 26, 2009

Blank page retained for pagination

ABSTRACT

This is a summary of talks given at the First Annual Arctic Planning Session, November, 1958. The talks were on the subjects of: Lake Peters – The Arctic Coastal Research Program; The Ice-Free Land Program; Arctic Ocean Studies; Arctic Lake Research; and related topics of general interest.

Figure A-1.

Participants in the Arctic Terrain Research Planning Session held by the Terrestrial Sciences Laboratory of Geophysics Research Directorate at the Boston Museum of Science, November 18-20, 1958. Left to right:

Front row:

Dr. David Smith
Mr. Richard Tracy
Capt. Donald W. Klick
Mr. Stanley M. Needleman
Dr. G. William Holmes
Lt. Col. Donald A. Shaw
Mr. L. W. Eminger
Dr. Henri Bader
Bernt Balchen (Col. USAF, Ret.)
Mr. Kenneth Linell
Dr. John B. Lyons
Miss Vivian Bushnell
Dr. Geoffrey Hattersley-Smith
Mr. Reid Neufer

Second row:

Mr. David F. Barnes
Mr. Arthur E. Collin
Dr. Joseph M. Quashnock (Lt. Col. USAF)
Mr. William E. Davies
Lt. Col. Robert H. Wilson
Major Willie Knutson
Mr. Carlton E. Molineux
Dr. Fernand dePercin
Col. Louis DeGoes
Dr. Roy Kratz
Dr. Max Britton
Dr. Svenn Orvig

Third row:

Dr. Joseph H. Hartshorn
Mr. Peter Larsson
Major Ray Baker
Mr. Richard B. Black
Mr. Earl H. Moser, Jr.
Dr. W. David Kingery
Dr. A. Lincoln Washburn
Mr. Joe O. Bell
Dr. Walter A. Wood
Dr. Earl T. Apfel
Dr. Peverill Meigs

Fourth row:

Capt. Robert A. Gray
Mr. Frank Riddell
Lt. Col. Jack W. Streeton
Mr. Peter H. Wood
Col. Walter H. Parsons
Mr. Melvin Hermann
Mr. Charles R. Lewis
Dr. Frank C. Whitmore, Jr.
Mr. Paul Walker
Dr. George Keller
Mr. William Maloney

Fifth row:

Capt. Thomas D. N. Douthit
Mr. Martin L. Haas
Capt. Benjamin Hoskins
Dr. Wilford F. Weeks
Dr. Max Brewer
Dr. Waldo K. Lyon
Dr. Arthur Lachenbruch

TABLE OF CONTENTS

I. INTRODUCTION

Colonel Louis De Goes 1

II. LAKE PETERS -- ARCTIC COASTAL RESEARCH PROGRAM

Geological and Hydrological Investigations at Lake Peters
G. W. Holmes 2

Lake Peters Meteorology
Fernand dePercin 7

Barter Island and Arctic Coast Geological Investigations -- 1958
C. R. Lewis 9

III. ICE-FREE LAND PROGRAM

Background of Greenland Studies
William E. Davies 12

Ice-Free Land Studies
Stanley M. Needleman and Captain Donald W. Klick 15

IV. ARCTIC OCEAN STUDIES

Arctic Ocean Research
Irene M. Browne 20

Station Alpha: Geophysical Investigations
Kenneth L. Hunkins 23

Geophysical Investigations by the U. S. Geological Survey on T-3
G. V. Keller 26

Preliminary Report on the Surface Morphology of T-3
David D. Smith 31

Oceanographic Survey on IGY Drift Station "Bravo" T-3
Arthur E. Collin 36

TABLE OF CONTENTS (contd)

V. ARCTIC LAKE RESEARCH

Preliminary Results of a Study of a Permanently Frozen Lake in Greenland
David F. Barnes 42

VI. GENERAL PAPERS

Utilization of Ice and Snow in Arctic Operations
W. D. Kingery 43

The Sea Ice Physics Project 1954-1959
W. F. Weeks 47

Geophysical Studies in Permafrost
Max Brewer 49

Thermal Studies in Arctic Ice and Permafrost
A. H. Lachenbruch 51

Arctic Applications Research
Carl E. Molineux 53

The C-130 as a Support Aircraft
Captain T. D. N. Douthit 55

Use of Lighter-than-Air Craft in the Arctic
Captain H. B. VanGorder 58

Military Significance of Ice-Free Land in East Greenland
Colonel Bernt Balchen 63

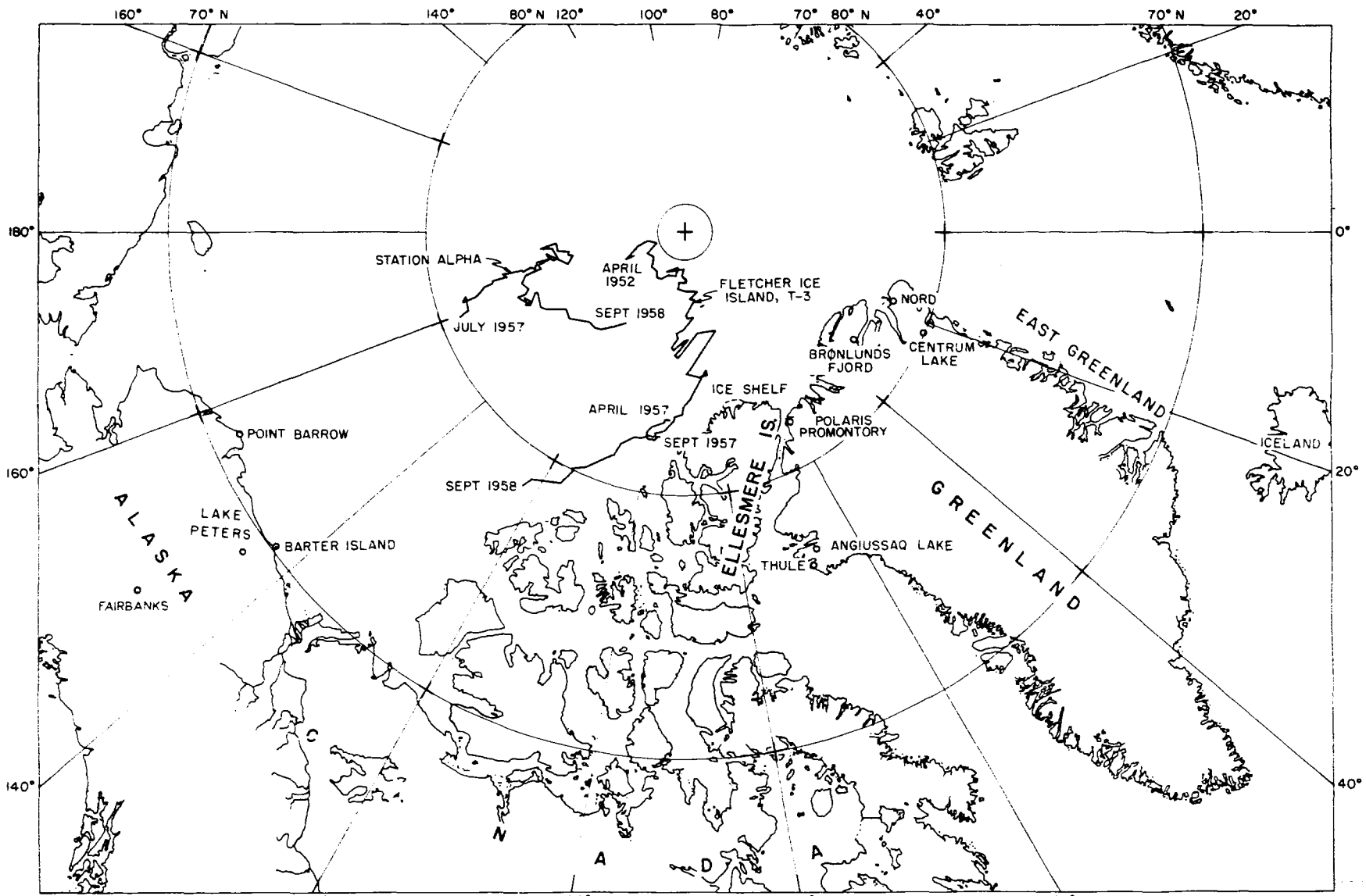


Figure A-2. Sites at which arctic terrain research has been carried out. Paths of the Drifting Stations are given through September 1958.

I. INTRODUCTION

INTRODUCTION

Colonel Louis De Goes, USAF

The objectives of the First Annual Arctic Terrain Research Planning Session were:

1. To evaluate results of the 1958 field research program.
2. To formulate preliminary plans for the 1959 field season.
3. To prepare a preliminary logistics and communications plan for the 1959 field season.
4. To exchange information with other individuals and agencies concerned with arctic terrain research and to explore possibilities for further joint participation in pursuit of common objectives.

Originally, the Planning Session was scheduled to be held at the Terrestrial Sciences Laboratory, 11 Leon Street, Boston. Participation was at first limited to only a few key personnel. Responses from individuals and agencies concerned with arctic research were quite vigorous, and it became obvious that the limited laboratory facilities could not accommodate all those who desired to attend the Planning Session.

Dr. Walter Wood and the Arctic Institute of North America came to the rescue and graciously donated their support in acquiring a suitable site. Our deepest appreciation is due Dr. Bradford Washburn, Director of the Boston Museum of Science, for his cooperation in making available to us the excellent facilities and stimulating environment of the Museum of Science.

Results of the First Planning Session were indeed gratifying and exceeded all expectations. We wish to thank sincerely all participants for their enthusiastic and valuable contributions and hope that they may find time to participate in the Second Annual Planning Session which will be held at the close of the 1959 field season.

II. LAKE PETERS -- ARCTIC COASTAL RESEARCH PROGRAM

GEOLOGICAL AND HYDROLOGICAL INVESTIGATIONS AT LAKE PETERS

G. W. Holmes, U. S. Geological Survey

The geological studies were directed toward the surficial deposits, primarily glacial in origin, which fill the valleys and cover the foothills in the vicinity of Lake Peters. Approximately 320 square miles were mapped from the main camp (Fig. 1), including the Franklin Mountains which are composed largely of early Paleozoic metamorphic rocks.

North of Lake Peters the bedrock is composed of less resistant Paleozoic and Mesozoic sedimentary rocks, some of which form anticlinal hills and mountains. During the Pleistocene epoch glaciers moved from cirques in the Franklin Mountains through the larger valleys and spread northward into the rolling foothill zone. The glacial deposits indicate three major glaciations, each sucessively less extensive. The oldest, termed the Chamberlin glaciation, pushed northward toward the Sadlerochit Mountains, and flowed from at least three major valley glaciers. The largest glacier was from the Hulahula River, but major ice streams also came down the Lake Peters trough and the Sadlerochit River. The deposits from this oldest glaciation are subdued and little of the original topography is preserved. The next glaciation, named for Lake Schrader, left recognizable end moraines (Fig. 2) and outwash terraces on the foothills, and terminated a few miles north of Lake Schrader. An independent glacier also moved down the Huluhula River and the Sadlerochit River. The youngest of the major advances stopped at the north end of Lake Peters. This glaciation, named for Lake Peters, also moved down other valleys, but did not reach the foothills. One or possibly two recent stages are also recorded as end moraines near the present glaciers. Figure 3 is a sketch map of glacial deposits in the area.

Permafrost underlies the entire area, with the possible exception of the lake basins. The permafrost table is shallow, typically 2 to 4 feet, and the active layer is normally saturated in the summer even in gravel deposits. Frost forms are found on almost all of the surficial deposits, with the greatest development on the oldest and most extensive

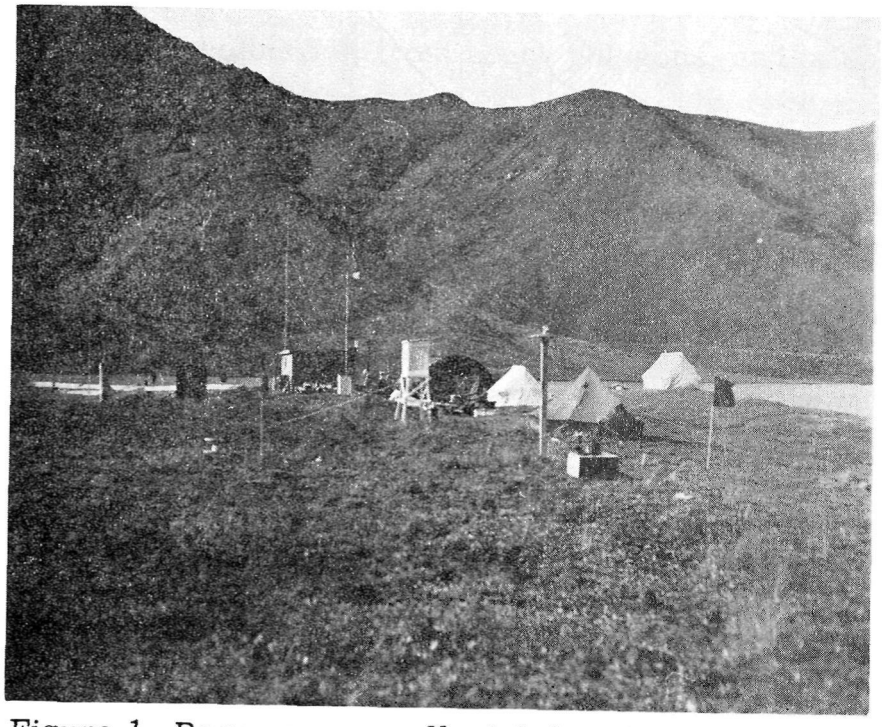


Figure 1. Base camp on alluvial fan at Lake Peters. Meteorological instruments in foreground.

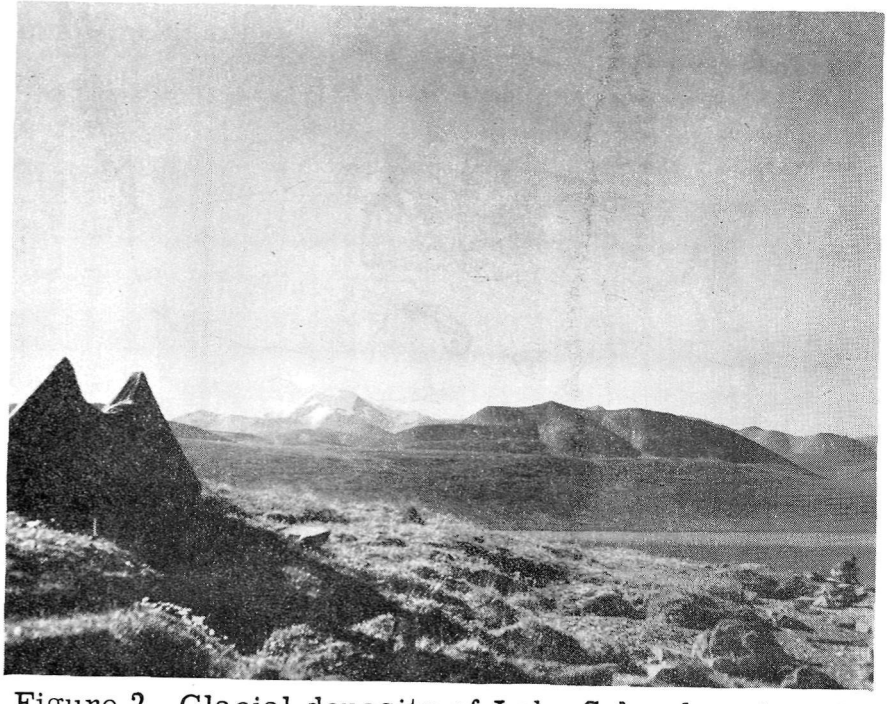
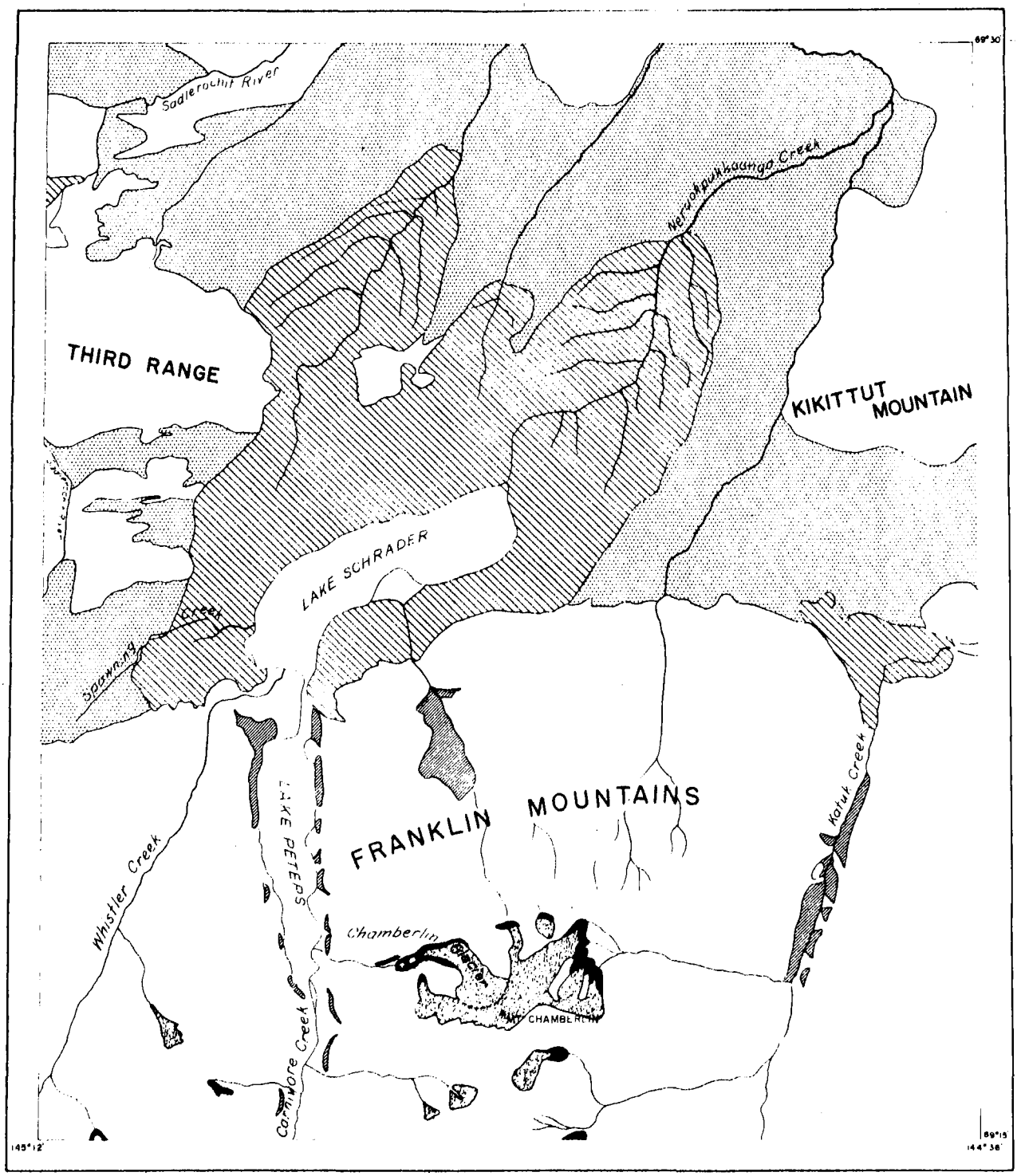


Figure 2. Glacial deposits of Lake Schrader stage in foreground and across the lake. Mt. Chamberlin background.



SKETCH MAP OF GLACIAL DEPOSITS, MT. MICHELSON B-2 QUADRANGLE
(MT. CHAMBERLIN DISTRICT), BROOKS RANGE, ALASKA

SCALE

0 1 2 3 Miles

LEGEND

PRESENT GLACIERS | CINQUE MORAINE | PETERS MORAINE | SCHRADER MORAINE | CHAMBERLIN MORAINE

Figure 3.

moraines. The most common features are frost mounds which occur on nearly all of the flat uplands. Stone rings, terracettes, garlands, tussocks, earth hummocks, frost crack polygons, and talus are also well distributed.

Active earth flows apparently are reducing the slopes at a rapid rate. At least 12 flows have formed on the shores of Lake Schrader since 1950, and a large flow occurred there in August of 1958 (Fig. 4).

The hydrological program was conducted by Daniel G. Anderson of the Water Resources Division, U. S. Geological Survey. Three recording stations were established and maintained through the summer; two near the snout of Chamberlin Glacier (Fig. 5),and one on Lake Schrader. The data will be correlated with the climatic record from Chamberlin Glacier. The record suggests that a major part of the ablation flows immediately into the stream. The lake record makes it possible to compute the outflow volume of the lake throughout the summer, and other measurements make it possible to estimate the inflow from the several inlets. Other hydrological studies include sampling of precipitation, glacial ice, meltwater, and lake water. Mr. Anderson also surveyed about 25 movement stakes on the glacier and made studies of channel morphology.

Figure 4. Earthflows on Lake Schrader; August 1958.

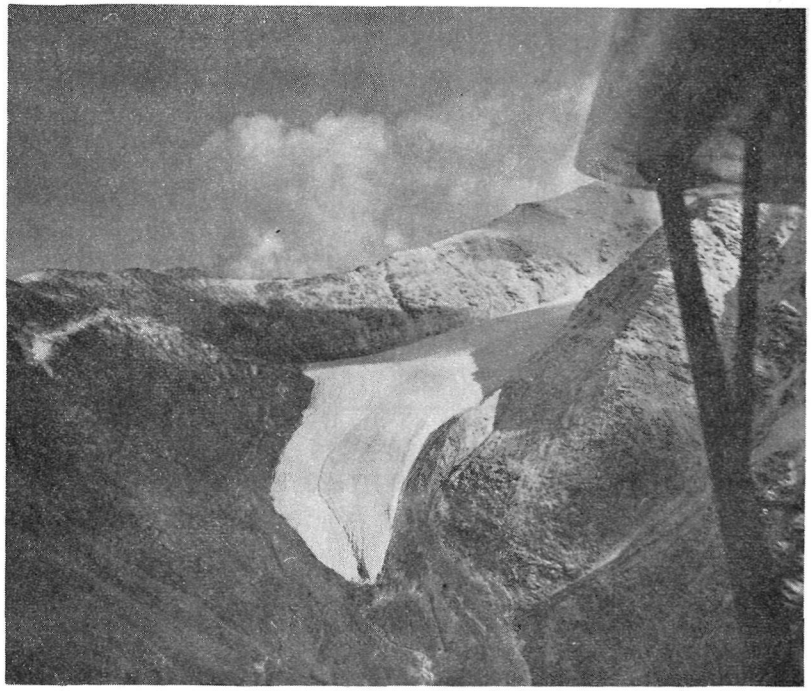


Figure 5. Chamberlin Glacier on northwest slope of Mt. Chamberlin. Visible part of glacier is approximately 5600 feet long.

LAKE PETERS METEOROLOGY

Fernand dePercin, QM R&E Ctr.

Meteorological measurements and observations were made from 12 July to 27 August 1958. Observations were made three times daily, at 0800, 1400 and 2000 AST. Twice during the period, observations were made bi-hourly from 0800 to 2000 hours AST to obtain information on the daytime climatic regime.

Although data are scarce, indications are that summer 1958 was much warmer, drier, and less cloudy than usual. At Lake Peters, mean hourly temperatures ranged from a minimum of about 44°F at 0400 hours AST to a maximum of about 54°F at 1100 hours AST. The lowest temperature recorded was 34°F; the highest 65°F (Fig. 1). The small range in mean hourly temperatures (10°F), and between absolute maximum and minimum (31°F), reflects the influence of the adjacent lakes.

Wind speeds averaged 2.7 knots at 0800 hours; 7.5 knots at 1400 hours; and 5.9 knots at 2000 hours. The orientation of the deep glacial valley was such that winds blew either from the north or south. Most frequently, however, the wind was from the north. In the early morning hours, heating by the sun established a valley breeze. This breeze, usually well-developed by midmorning, blew from the north across the cool lake waters causing sudden drops in temperature and effectively limiting maximum temperatures. On clear nights, a light katabatic wind blew from the mountains to the south.

In general, skies were cloudy and ceilings moderately low during the period. Average sky cover at 0800 hours was 6.2 tenths; at 1400 hours, 7.3 tenths; and at 2000 hours, 6.8 tenths. For these same hours, ceiling heights averaged 3,730 feet, 3,440 feet, and 2,880 feet respectively.

Precipitation was recorded on 31 of the 47 days (Fig. 2), but the total received was only 2.35 inches. No snow fell at the camp, precipitation generally occurring as drizzle or light rain.

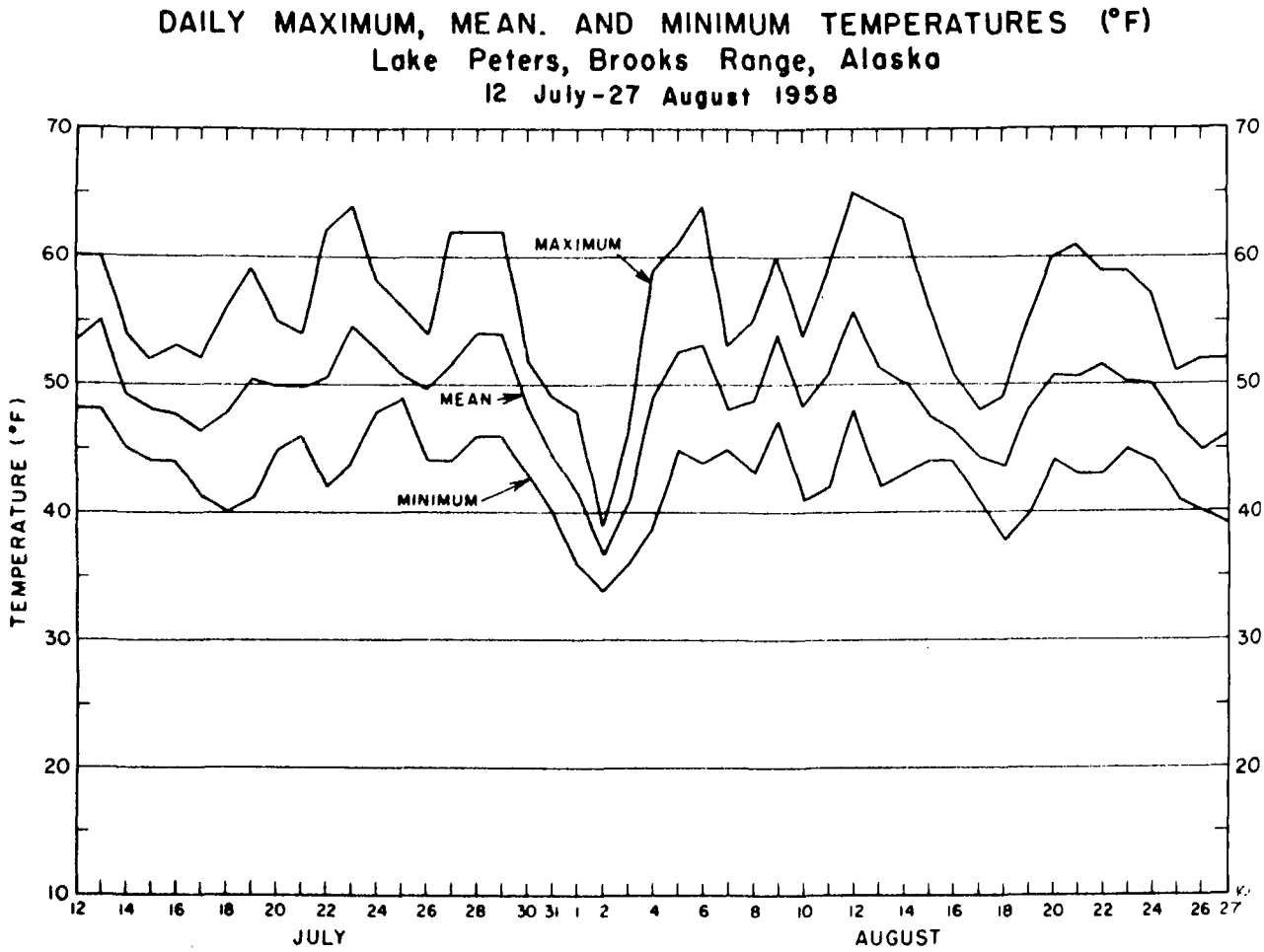


Figure 1

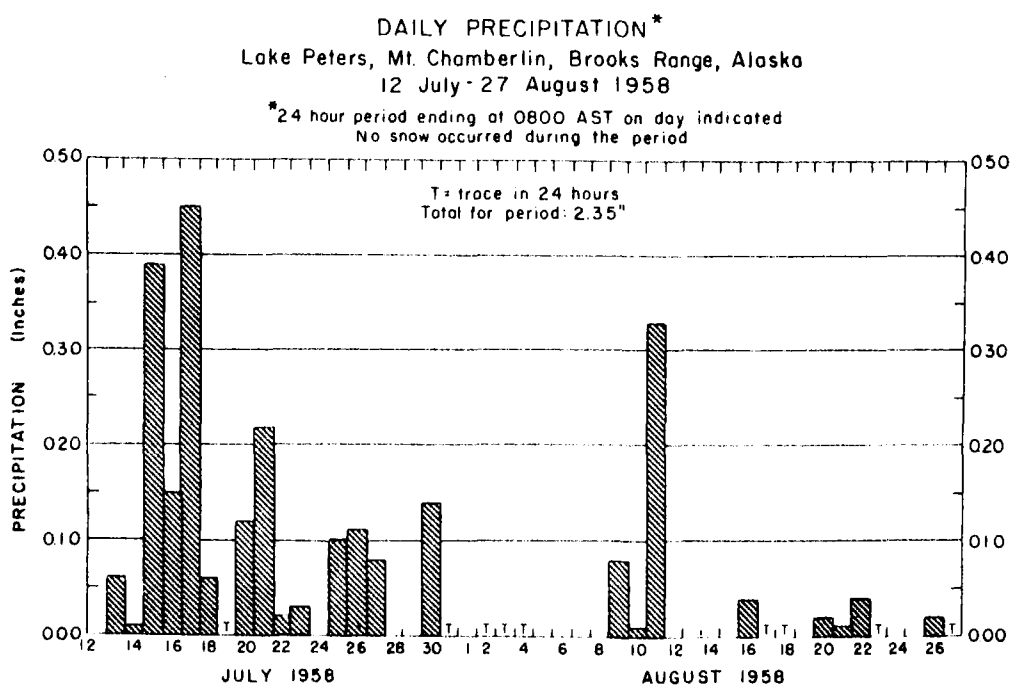


Figure 2

BARTER ISLAND AND ARCTIC COAST GEOLOGICAL INVESTIGATIONS - 1958

C. R. Lewis, U. S. Geological Survey

During the summer of 1958 a preliminary geologic survey was made of surficial deposits in the coastal area of northeastern Alaska between the Canning River and the Canadian border (Fig. 1). Field investigations were done both by ground surveys in selected localities in the central and western parts of the area and by low-flying light float planes. The extensive use of aircraft that had been planned was not possible, and only a very hasty air reconnaissance was accomplished in much of the eastern third of the area. This survey covered parts of two physiographic provinces: the relatively wide Arctic Coastal Plain and the adjacent zone of moderately dissected piedmont that in part makes up the Northern Foothills of the Brooks Range.

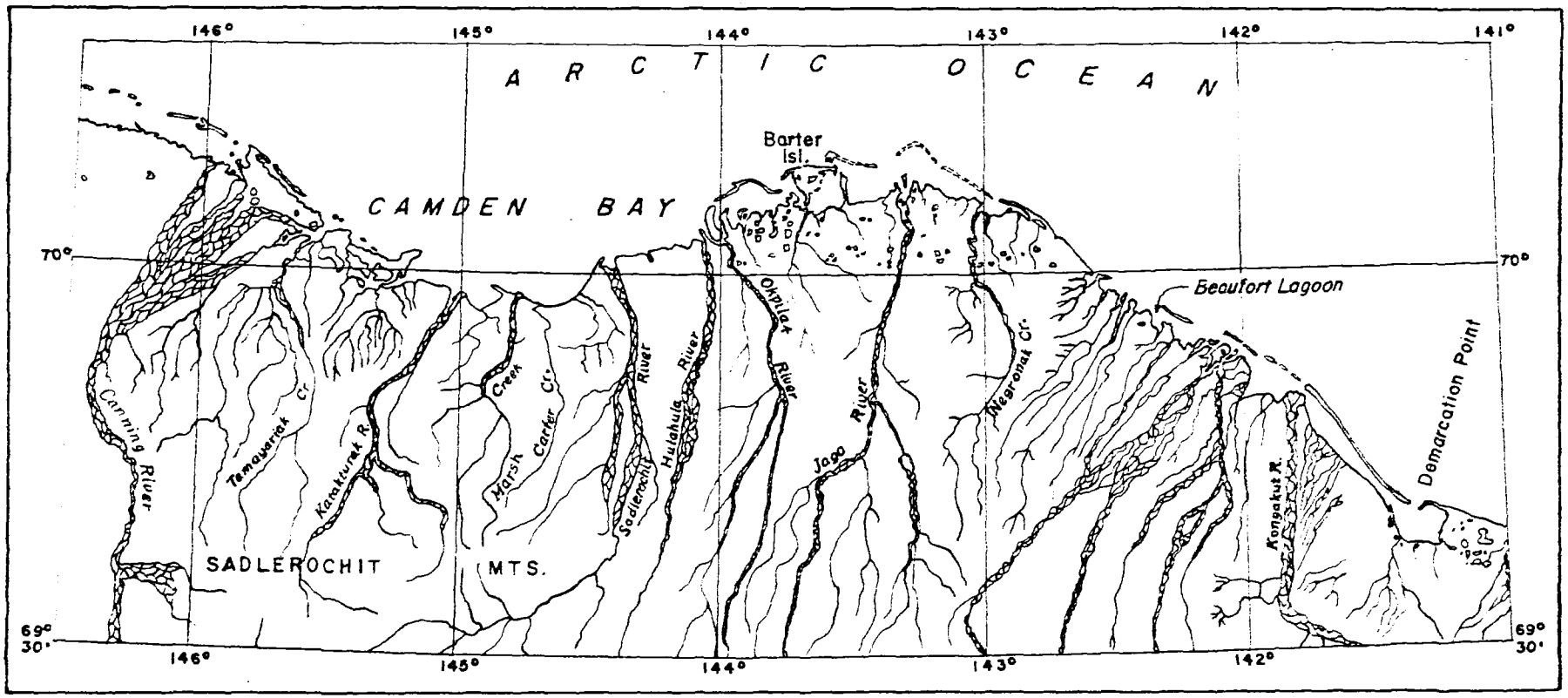
The Coastal Plain is an extremely flat, little-dissected tundra plain; it is non-existent in one locality and up to 20 miles wide in other places. Slopes are generally less than 1% and in wide areas are less than 0.5%. Eight to ten large rivers fed by snow and ice in the mountains cross the plain in shallow, wide valleys. A few short small streams fed by melting ground ice rise in the Coastal Plain. Small lakes and ponds are fairly common in the central and western parts of the Coastal Plain, but are scarce elsewhere; they commonly show a north-south orientation. The Coastal Plain is covered in most places by surficial deposits of poorly sorted gravel and sand. These unconsolidated deposits occur in wide floodplains and discontinuous terraces along the major rivers as well as in blanket deposits covering interstream areas. Other surficial deposits in the Coastal Plain, in addition to this widespread sand and gravel, are the sand and gravel of narrow beaches, spits, and barrier islands along the coast, aeolian silt and fine sand in the deltas of several major rivers, local coastal deposits of marine silt, local peat deposits up to 10 feet thick, and isolated erratic boulders that occur at intervals along the shoreline.

The moderately dissected piedmont to the south is also largely covered by extensive thick deposits of rounded boulders and gravels that may represent remnants of one or more ancient glacial outwash plains. These are the deposits called "upland gravels" by Leffingwell.* Narrow terraces along major rivers mark several younger outwash plains. In many places in the piedmont, however, the upland gravels are absent; the surficial material is silty colluvium derived from the underlying weakly consolidated Pliocene shale. This shale is exposed as far north as the coast at Camden Bay and as far east as Negronak Creek, about 7 miles from the coast. South of Camden Bay, the upland gravels, cropping out as narrow ridges that distinctly parallel an anticlinal structure in the underlying shale, may indicate post-Pleistocene folding. The upland gravels are bluff and ridge-forming deposits; the Pliocene shales form gentle slopes, commonly show a fine-textured drainage pattern, and, on banks where overlain by gravels, commonly slump forming solifluction terraces.

Permafrost is continuous throughout the area; in few places was the depth of thaw observed to exceed 18 or 20 inches. The ground was rarely observed thawed below the more-or-less uniform surface layer of tundra vegetation and muck. Permafrost features abound in the area. Most surfaces are tessellated by soil polygons; marshy low center polygons are developed over much of the floodplains and in the bottoms of the many recently drained lakes and ponds; high-center polygons are strongly developed in peat and thick muck on river terraces and other nearly level surfaces. Over much of the Coastal Plain, the small frost mounds are the only conspicuous relief features. Ground ice is well exposed, especially along parts of the coast; melting of the ice is responsible for an extremely rapid retreat of the shoreline.

*Leffingwell, E. DeK., 1919, The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, p. 130-133.

Barter Island and Arctic Coast Geological Investigations: Location of Project Area



Compiled from various sources
U.S. Geological Survey

10 0 10 20
Statute Miles

SCALE 1:1,000,000

Figure 1.

III. ICE-FREE LAND PROGRAM

BACKGROUND OF GREENLAND STUDIES

William E. Davies, U. S. Geological Survey

In 1951 the U. S. Geological Survey was approached by the Weather Bureau and the Air Force to evaluate areas in North Greenland for the siting of a year-round weather station and a supporting airfield. Station Nord was established in northeast Greenland as a result of this work. During this investigation the U. S. Geological Survey evaluated 20 sites (for example, Fig. 1) and concluded that these sites could be used for landing the heaviest aircraft with little or no surface preparation.

In 1955 the Air Force Cambridge Research Center called upon the U. S. Geological Survey to utilize and expand the existing site investigations in conjunction with a program for establishment of emergency airfields in ice-free lands of the Arctic. In the summer of 1956 field investigations were made at Centrum Lake and Bronlunds Fjord, and 1957 saw the successful test landing of a C-124 at the Bronlunds Fjord site.

The selection of sites is based primarily on photogeology backed by considerable field experience. In most areas the sites are at points never previously visited on the ground. Results so far indicate that the photogeologic methods are sound and are the key to low cost, rapid site selection and development in the Arctic.

The field investigations in 1958 were at Polaris Promontory. This area is 375 miles north of Thule and 300 miles west of Nord. The promontory is 50 miles long and 25 miles wide. On the north it is bounded by Newman Bay; on the south by Polaris Bay. A broad lowland extends across the promontory in a southwest-northeast direction and is bounded by low plateaus and mountains. This lowland is on a deposit of marine clay and silt that has been uplifted 350 feet above the sea. The area is very arid (Fig. 2) and precipitation is less than 2 inches a year. As a result the clay and silt are strong and stable. Two large rivers cut across the plain near its edges. Broad terraces were cut by the rivers, and gravel deposits up to 10 feet thick were laid down

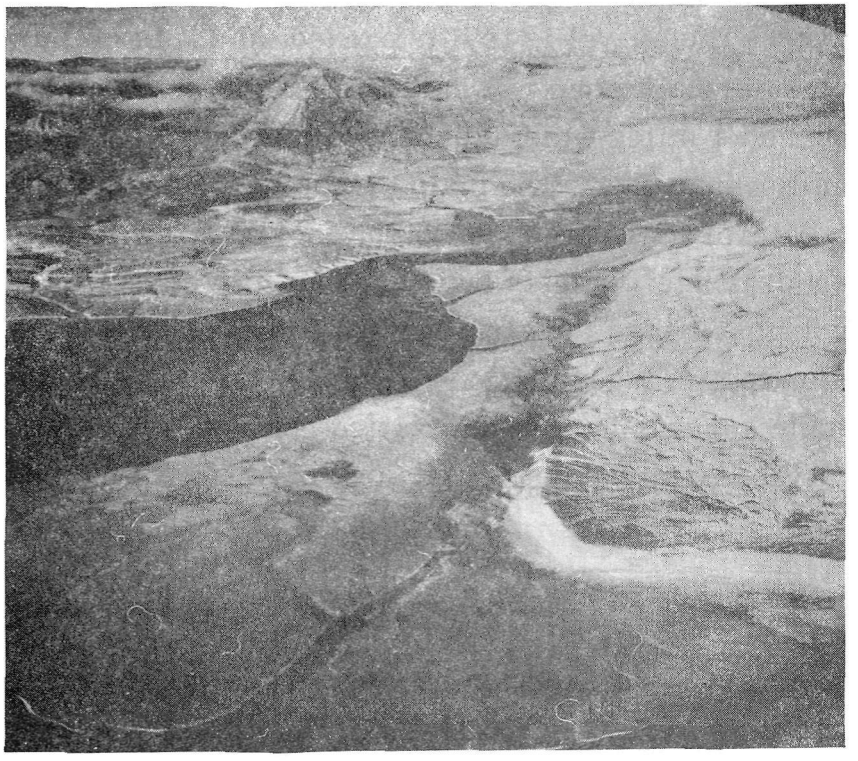


Figure 1. River terraces at west end of Centrum Lake, northeast Greenland. Folded Silurian limestones form mountains 2000 feet high in background. Graesrig Elv (river) in middleground.

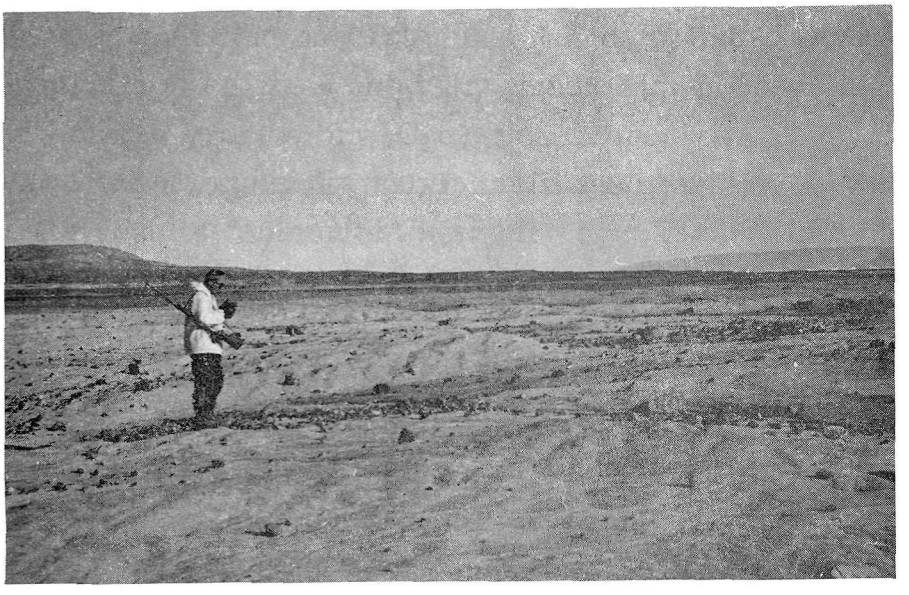


Figure 2. Typical high latitude Arctic arid lands. Clay beds at Bronlunds Fjord, north Greenland.

on the terraces. The gravel is tightly packed, and it is on this that the Polaris Promontory air strip was laid out. The strip is on a terrace 10 miles long and 4 miles wide, adjacent to the Graystone River, about 6 miles from Newman Bay. The plain slopes to the northwest at 50 feet to the mile. Microrelief ranged up to one foot on a few low mounds and along shallow drainage channels but were easily graded off. Many depressed polygons cross the strip but are 2 inches or less in depth.

In addition to site investigations, extensive geologic reconnaissance and topographic surveys have been carried out at all sites visited. As a result a much better picture of the geology of north Greenland is being produced.

ICE-FREE LAND STUDIES

S. M. Needleman and Captain D. W. Klick, USAF
AFCRC

Research on ice-free land is aimed at locating, evaluating, and testing natural land features in the Arctic in order to determine arctic capability to support air operations and to fulfill the need for minimum prepared runways to serve as low cost emergency airstrips. The general approach to the problem is one of environmental research in that it involves the combination of such scientific fields as soil sciences, soil mechanics, glacial geology, military and engineering geology, climatology, civil engineering, and the study of permafrost.

Ice-free land is defined as those coastal areas free of snow and ice in the summer and occurring in the Arctic, generally in latitudes higher than 60°N (Fig. 1). Hundreds of thousands of square miles of this type of terrain border Alaska, Canada, and Greenland. Studies thus far have been concentrated on Greenland, although much is known about many such areas in Alaska and Canada. However, much remains to be accomplished on this problem throughout the Arctic.

The utilization of such terrain for siting air facilities is of paramount importance. Results of research already accomplished have demonstrated that many arctic sites, such as at Bronlunds Fjord (Operation Groundhog - 1957) and Polaris Promontory (Operation Groundhog - 1958), can be easily converted into useful airstrip facilities at relatively low cost. In addition, the results contribute toward the development of techniques to reduce the cost of installing facilities in the Arctic by improving site selection.

Research on the ice-free land problems has been conducted for the past few years by scientists of this Laboratory and Air Force contractor personnel of the U. S. Geological Survey. The results have been the identification and description of numerous such suitable areas located on the north and east coasts of Greenland, thirty sites on the north and twenty-two sites on the east.

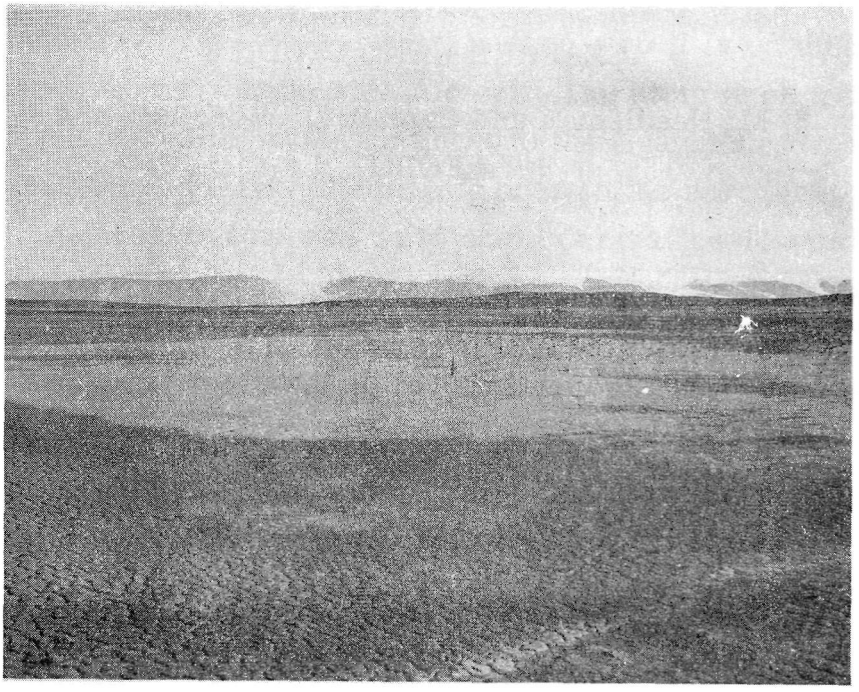


Figure 1. Dry, hard-packed clay lake bed at Bronlunds Fjord (82° 08' N, 31° 18' W) near edge of ice cap -- typical of ice-free land areas.

Figure 2. C-124 aircraft on unimproved natural soil airstrip at Bronlunds Fjord. One touch-and-go letdown and two test landings and takeoffs were successfully made.

The specific sites are first identified and mapped, generally at a scale of 1 inch to 1 mile, by photogeologic techniques and the extraction of information from all available sources, including the literature. The laboratory studies also provide factual information on the local surficial geology, bedrock geology, drainage, soil and foundation conditions, grading, approach hazards, accessibility, water supply (potable and construction), available construction materials, and related engineering data. Field investigations are then conducted, directed toward quantitative evaluation of the selected sites. Representative sites with different terrain conditions are selected for actual aircraft test landings or demonstrations to verify the methods (Fig. 2). These tests assist in modifying proven techniques where necessary. Present methods are well documented in the reports listed in our Laboratory bibliography.

A field project was conducted by Geophysics Research Directorate scientists under Operation Groundhog - 1958 to investigate and test ice-free sites on Polaris Promontory (81° 35' N, 59° 45' W), the northwest tip of Greenland. The operation included detailed ground surveys of several sites. The operation was staged from the icebreaker USS Atka and was supported by two helicopters. This project was a continuation of a test program initiated in 1957 when a successful landing was accomplished by a C-124 on an unprepared runway on ice-free land in northern Greenland.

Investigation of Polaris Promontory resulted in the selection of an airstrip 200 ft wide and 5,000 ft long, with clear approaches and a nearly flat surface. Five test pits were dug to determine the soil profile, and soil samples were taken from them for sieve analyses, Atterberg limit tests, and moisture content determinations (Fig. 3). Soil temperatures and depth to permafrost also were noted. Approximately 2800 shearing strength readings at regular intervals along the runway and to various depths were obtained with a manual cone penetrometer and an airfield penetrometer. An improvised compaction test was performed on the surface and soil in four locations.

The test pits revealed a uniform soil profile throughout the entire strip. Classification tests placed the top layer (which extends to about 6 in below the surface except in the drainage channels) in the category

Figure 3. Typical soil testing procedures at ice-free land areas -- pit to determine soil profile and to obtain soil samples, and penetrometers to determine soil strength.

of a firm, poorly graded gravel and sand mixture with a silt binder (46% gravel, 42% sand, 12% fines). The top layer in the drainage channels extends to varying depths and consists of a very fine sandy tan silt. Below the top layers and down to permafrost (which is at an average depth of 2 ft 10 in) the soil becomes a dense, poorly graded sandy gravel with very little fines (69% gravel, 29% sand, 2% fines). In all cases there is very little coarse or medium sand present and all fines exhibit very little, if any, plasticity.

Penetrometer readings indicate a fairly soft surface but a rapid increase in shearing strength with depth. At one inch depth an average California Bearing Ratio (CBR) of 4.1 was obtained, and at 3 in, it increased to 14.7. In only 10 isolated locations was the CBR less than 10 at 3 in, and then never less than 8.5. The softer areas are in the drainage channels, but even there the firmness of the soil gives an adequate CBR at much less than a critical depth. The very dense gravel layer lies only about 6 in below the surface in a great portion of the area, and here CBR values are in the 25 plus range.

After it was determined that the soil was strong enough to support aircraft, a small amount of grading was accomplished with a jeep-mounted snow blade to knock down the few high spots. A radar reflector was placed at each corner of the strip to serve as markers, and orange flags located every 100 ft along the center line and every 500 ft along the side lines were left standing to aid in relocating the strip.

ARCTIC OCEAN RESEARCH

Irene M. Browne, AFCRC

The current research program conducted by the Terrestrial Sciences Laboratory in the Arctic Ocean was located on the IGY Drifting Stations Alpha and Bravo, and is still in operation on Bravo. Project Ice Skate, as the Arctic Ocean activity has been designated, was initiated in early spring 1957. The Alpha camp, shown in Fig. 1, was set up by the Air Force on a large, smooth floe on the pack ice. The floe measured approximately one mile by one half mile in size, and about ten feet in thickness. The station remained in continuous operation until a major breakup severed the camp from the runway and endangered personnel. The Alpha evacuation on 6 November 1958 temporarily terminated the ice pack program.

The second Drifting Station, Bravo, is also known as Fletcher's Ice Island, T-3. Initially sighted in 1947 along the Canadian Archipelago, the island has drifted 2500 miles in the Arctic Ocean during its known history. In contrast to the ice pack station, T-3 is about 9 × 4-1/2 miles in area and 170 feet thick. It was occupied as a combined weather and geophysical research station for thirty months from 1952 to 1955. The geophysical program was under the direction of Mr. A. P. Crary of this Laboratory. When the IGY program commenced in 1957, the Air Force set up the new, modern, comfortable and efficient camp shown in Fig. 2.

The Laboratory program in the Arctic Ocean encompasses the general scope of geophysical exploration of unknown areas. Seismic and resistivity techniques are employed to define the physical character of the ocean, its depth, and sub-bottom layering. Magnetic and gravity values are read daily. The movements of the ice and the physical and biological properties of the Arctic Ocean are being investigated. The ice itself is being subjected to structural, morphological, and chemical analysis. These are, in brief, the major investigations sponsored by the Laboratory at the Drifting Stations.

The research personnel and facilities of several agencies are

IV. ARCTIC OCEAN STUDIES

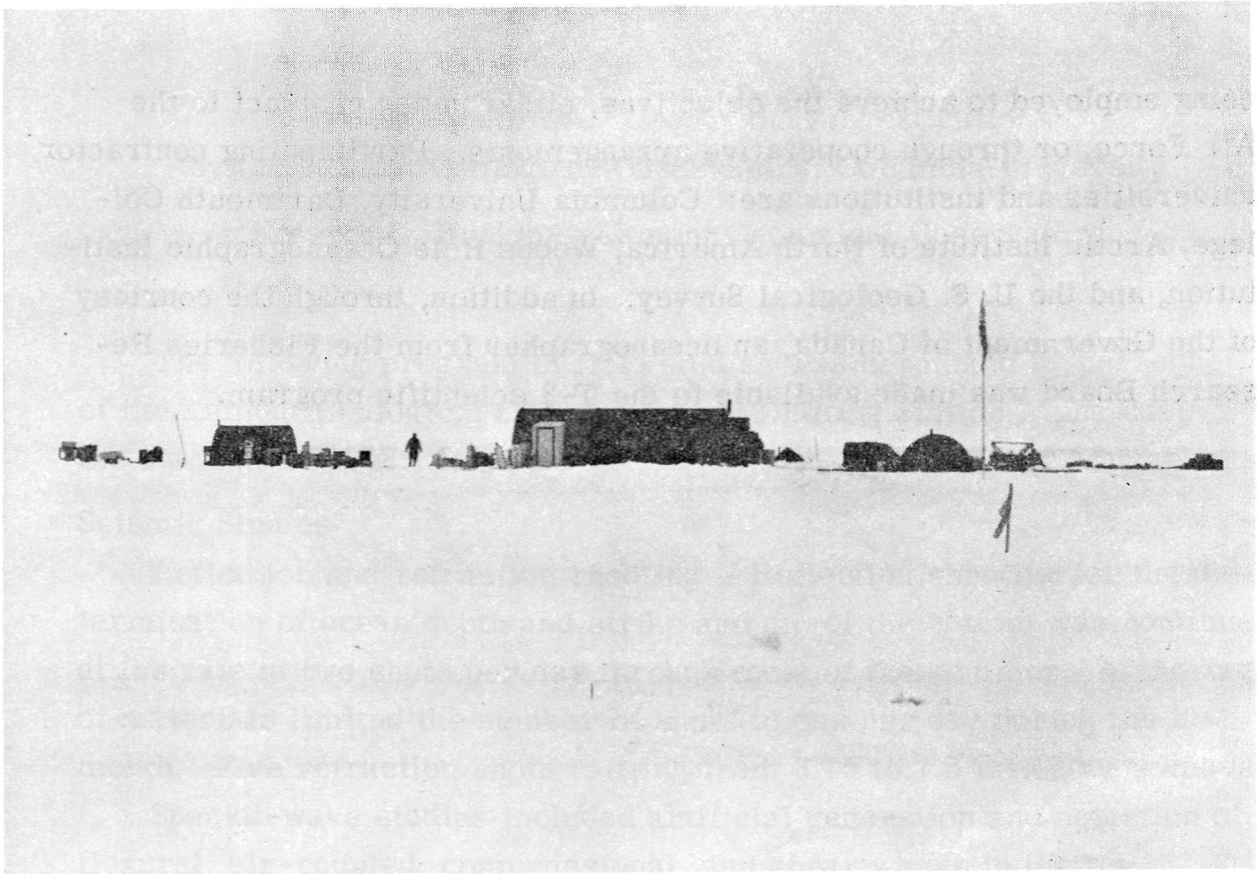


Figure 1. General view of the camp site at Drifting Station Alpha, 28 May 1957.

Figure 2. View of Drifting Station Bravo (T-3) taken from the ionosphere antenna tower, 12 July 1957.

being employed to achieve the objectives, either under contract to the Air Force, or through cooperative arrangements. Participating contractor universities and institutions are: Columbia University, Dartmouth College, Arctic Institute of North America, Woods Hole Oceanographic Institution, and the U. S. Geological Survey. In addition, through the courtesy of the Government of Canada, an oceanographer from the Fisheries Research Board was made available to the T-3 scientific program.

STATION ALPHA: Geophysical Investigations by the Lamont Geological Observatory, Columbia University

Kenneth L. Hunkins, Lamont Geological Observatory

The following program of field studies was conducted by personnel of the Lamont Geological Observatory on Drifting Station Alpha during the summer of 1958:

Seismic Studies

Reflection and refraction shooting -- Reflection shooting for the determination of ocean depth and strike and dip of the bottom was continued at the rate of two shots per day through most of the summer. A shortage of materials limited the number of shots to one per day during the last month. Five refraction shots ranging from 3.75 to 7.5 miles were made.

Special-wave studies included artificial generation and detection of flexural, air-coupled, compressional, and shear waves in the ice.

Underwater sound studies included recording the shots on T-3 both on tape and photographically, using geophones and a hydrophone for transducers; recording ambient noise level in the ocean at various depths; and determination of the reflectivity coefficient of the water-ice interface.

Gravity

Readings on the Frost gravimeter were continued at the rate of two per day.

Magnetics

Transit Magnetometer -- Determinations of the declination and horizontal intensity of the earth's magnetic field were made at least once a week.

The Askania Variograph measured continuously the relative changes of three components of the earth's magnetic field.

Oceanography

Current Measurements -- (1) Velocity profiles were measured daily with a drag-meter at depths of 2, 4, 8, 16, 32, 50, 75, 100, 125, and

400 meters, and with a Gurley-meter at 2, 4, 8, and 16 meters.

(2) The Ekman spiral was measured by change in azimuth of the drag-director of the drag-meter.

(3) Measurements of permanent currents were attempted by three lowerings of the Thorndyke current-meter and installation of a drag-meter at a fixed depth of 400 meters.

Bottom Cores -- Four cores were obtained with the Ewing corer, including one on the slope of a prominent submarine rise that contained an orange-red clay not observed in any other core taken to date.

Bottom Dredgings -- Five bottom dredgings were made from which several specimens of ocean-bottom marine life and many rock samples were obtained, including a fossiliferous limestone measuring $10 \times 10 \times 4$ centimeters. A uniform sample for the purpose of age-dating the uppermost sediment was obtained by means of the Ekman-grab.

Water Samples -- Plankton samples and small marine animals were obtained at various depths.

Bottom Photos -- Using the Thorndyke bottom camera, photographs of the ocean bottom were obtained, both in color and in black and white (Fig. 1).

Ice Studies

Studies of the ice included (1) determination of its elastic properties through the seismic investigations mentioned above; (2) vertical density profiles; (3) photographs of the underside of the ice; (4) numerous ice-thickness measurements; (5) bottling an ice core for determination of C_{14} content; and (6) daily logging of local ice movement.

Navigation

Approximately one hundred positions were obtained by celestial navigation during the summer period. A continuous track of the floe's movement was plotted on the basis of these fixes and wind and current data.

Figure 1. An unusual "find" was this rock at the bottom of the Arctic Ocean, at approximately 83° 40' N, 160° W, in 2500 meters depth. The photograph encompasses one square meter and was taken by a Ewing suspended automatic camera.

GEOPHYSICAL INVESTIGATIONS BY THE U. S. GEOLOGICAL SURVEY ON T-3

G. V. Keller, U. S. Geological Survey

Geophysical studies were conducted by the U. S. Geological Survey on Fletcher's Ice Island, T-3, in the Arctic Ocean from May 1 to October 10, 1958. The program consisted of seismic measurements of ocean depths and sub-bottom character (Fig. 1), electrical measurements of bottom resistivity, and gravity and magnetic vector measurements. During this period, T-3 drifted from 80°20' N, 113°20' W to 78°10', 122°10' W. This course took the island along the edge of the continental shelf approximately 60 miles northwest of the Queen Elizabeth Islands.

Reflection seismic shots were recorded daily to determine the depth to the ocean bottom. The depth varied from a minimum of 3000 feet, recorded late in September, to a maximum of over 8000 feet, recorded in July. In addition to the reflections from the ocean bottom, fair to good sub-bottom reflections appear on most of the seismograms. Preliminary interpretation shows structural features such as anticlines, truncation of strata by the ocean bottom along the continental shelf, and homoclinal features. The greatest number of reflections, and presumably the thickest sedimentary sequence, was noted during late September in the vicinity of 78°30' N, 123° W.

For the deep resistivity measurements, current electrodes with a separation of 11,400 feet were placed in the ocean off the southeast edge of the island. Fifteen pickup electrodes were placed beneath the ice approximately in line with the current spread at distances of 150 to 40,000 feet from one end of the current spread. Storage batteries provided 268 volts to energize the current spread with approximately 10 amperes of current. The voltage between pairs of pickup electrodes was amplified and recorded on a pen-writing recorder. Resistivity soundings were recorded 22 times between May 26 and October 6. The data have not yet been reduced.

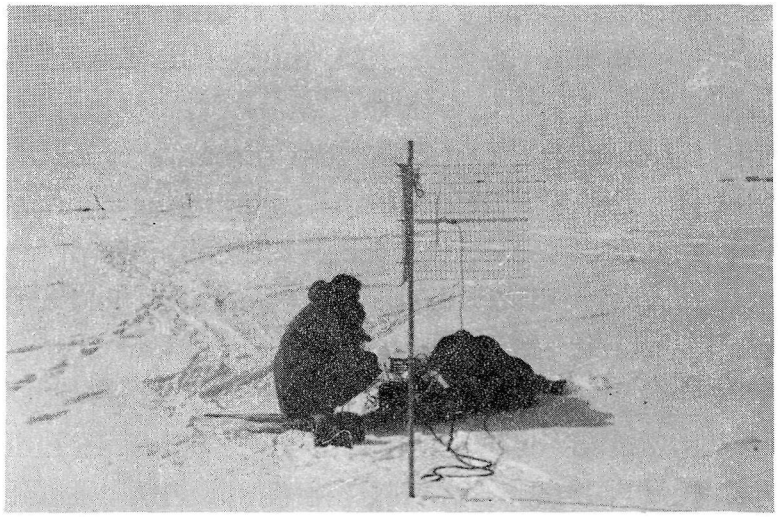


Figure 1. Preparing to shoot a refraction spread. Camp is shown in right background.

Figure 2. Moving "portable" electromagnetic gear used in measuring ice thickness.

In addition to the ocean bottom studies outlined above, several of the physical properties of sea water are being measured to provide information needed in the analysis of the seismic and resistivity data. These include measurements of natural potential, electrical resistivity, and temperature along vertical profiles in the water. The equipment consists of a hand-operated winch with 3200 feet of cable, a D. C. amplifier and a pea recorder driven by a flexible shaft run from a measuring wheel on the winch. The sensing element on the cable consists of a pair of electrodes for measuring resistivity and self potential and a thermistor for measuring temperature. Measurements were taken at bi-weekly intervals.

The thickness of island ice was measured by using an electromagnetic method (Fig. 2). Two loops of flexible cable with diameters of 15 and 30 feet respectively were laid out on the surface of the snow, with a separation of 100 to 500 feet between the coils. One coil was excited with an alternating current of 1.5 amperes using a battery-operated power oscillator. The voltage induced in the second loop was amplified and read on a vacuum-tube voltmeter. The current in the energizing loop was determined by measuring the voltage across a small resistor in series with the loop or by measuring the voltage induced in a small reference loop placed close to the energizing coil.

The voltage induced in the receiving loop is proportional to the mutual coupling between the coils. This mutual coupling depends, among other things, on the presence of conducting materials near the coils. In this case, the conducting material is the ocean water beneath the ice. Expressions for the mutual coupling between two coils on or above a one or two layer half space have been developed by other investigators. These equations are being evaluated over a wide range of parameters on the Datatron computer by the Computations Branch of the Geological Survey.

Measurements were made with several coil separations and various frequencies in the range 22 to 2,800 cps at each station. Estimates of ice thickness were obtained varying from 35 feet (at a location 1,000 feet west of the hydrographic station) to 170 feet (at a point near the old camp). A north-south traverse including 79 stations covered 19,350 feet from the south edge of the island.

In spite of instrumental difficulties, the results to date are very promising. If there are no inclusions of brine in the ice, it is believed that with proper instrumentation it would be possible to measure ice thicknesses of 100 to 200 feet with an accuracy of better than 5 percent. Moreover, the electromagnetic method is faster and can be more readily adapted to arctic working conditions than seismic methods.

A prototype of an electromagnetic device is being built which will measure the thickness of pack ice after being dropped from an aircraft. Two horizontal co-planar coils are used. They operate at a frequency of 50 kilocycles, a separation of eight feet, and are suspended so as to be self-orienting. When far removed from any conducting material the voltage induced in the receiving coil is nulled by a reference voltage. However, when the apparatus is placed at a distance of about five feet or less above sea water, the circuit will become sufficiently unbalanced to trigger a radio telemetering device which will warn the aircraft that the combined snow and ice thickness is less than five feet. Some sort of auxiliary probe device may be necessary to measure the thickness of the snow, since for most purposes it should be subtracted from the ice thickness.

The frequency of 50 kilocycles is great enough to give the equipment adequate sensitivity. A higher frequency would require operation at over one megacycle to avoid ambiguities in the response curve, and at this frequency a number of undesirable effects might influence the operation of the apparatus. The eight-foot coil separation is adequate to give a warning signal on any predetermined thickness of ice up to 5 or 6 feet.

Compass headings and magnetic components were measured daily. The direction to magnetic north ranged from 64 to 127 degrees true. The bearing to magnetic north varied 15 degrees over one 15-hour period, reflecting the effect of diurnal change. The vertical magnetic component remained at about 30 times the horizontal component, varying less than 10 percent from the average.

A North American gravimeter with a dial constant of 0.21 mgls/unit was read twice daily. The closure error between ties to Thule, Greenland on May 5 and September 21 was 0.3 milligals. The instrument constant checked to 0.1 milligals against a University of Wisconsin Worden meter over a range of 47 milligals. A positive free air anomaly

predominated during May and June, as contrasted to later negative values. After correction for varying depth to the sea floor, assuming an average density of 2.65, a number of local gravity anomalies remained.

So long as T-3 continues to float near the continental shelf, it will be a valuable platform for the study of geologic structure. Current plans call for reoccupation of T-3 from March till October, 1959. The geophysical program will be much the same as described in this report, except that greater emphasis will be placed on gravity and magnetic vector measurements. The greatest effort will be concentrated on improving navigation on the island, since the accuracy of the geophysical data obtained so far is very high; and uncertainties in island position do not permit the best use of the data.

PRELIMINARY REPORT ON THE SURFACE MORPHOLOGY OF T-3

David D. Smith, Dartmouth College

A three-man party spent three and one half months on T-3 during the 1958 summer season studying the variation in and progressive development of the morphology of the ice surface. Attention was concentrated on the drainage basin of Opportunity Creek near the southeast edge of the island. Although of second order magnitude, this stream was representative for purposes of temperature and hydrologic measurements and for study of variation in channel characteristics.

An extended series of hydrologic discharge measurements was made at five sites along Opportunity Creek, and for comparison, at sites on two first magnitude streams. Runoff was greatest shortly after flow began but dwindled rapidly, and within a few days it dropped to the seasonal average of 1 to 2 cubic feet per second.

The topography of selected portions of the drainage basin was mapped in detail on a very large scale using a half-foot contour interval. The stream channel averaged 3 to 5 feet below the irregular surface of the interfluves. Local relief on the interfluves was typically 2 to 3 feet. The channel narrowed and deepened noticeably during the melt season.

Weekly ablation measurements at two separate ablation pole networks that straddle typical reaches of the stream provided detailed data on total ablation and on progressive changes in the slopes of the stream valley. The 1958 ablation season was apparently one of the longest and most intensive in the recorded history of T-3. An average of 2-1/2 to 3 feet of ice was ablated. As a result conditions were ideal for study and mapping of ice types, surface morphology, and microrelief.

An ice structure and lithology map (Fig. 1) was prepared for the Opportunity Creek drainage basin. Four major ice lithologies are present in the area: (1) Banded, coarsely crystalline ice has crystals commonly 4 in in diameter. The origin of this ice is not fully understood; the unit is restricted to the extreme southeast edge of the island. (2) Ice firn is composed of spherical grains one-quarter to one-half

inch in diameter. This unit is generally veneered with a melt-produced lag concentrate of silt and clay. The sediment is eolian in origin and initially is present in the ice as thin dirt bands 2 to 6 inches apart.
(3) Old lake ice (Fig. 2), which consists of elongate crystals 6 to 12 inches in diameter, occurs as parallel, narrow linear bodies up to tens of yards wide and hundreds of yards long. These bodies are 5 to 15 feet thick and are commonly lens-shaped in cross section. The lenses have indented edges which interfinger with the enclosing iced firn. They originated as channels and lakes during the buildup of the parent shelf along Ellesmere Island. Both the iced firn and the old lake ice units were described in 1955 by E. W. Marshall for the Ellesmere shelf.
(4) Modern lake ice occurs as 3 to 6 foot thick pads, irregular to circular in plan and up to several hundred yards in diameter. These pads generally are composed of two or more layers of candle-like crystals 6 to 12 inches long and 1 to 2 inches in diameter. This ice apparently records former lakes which were frozen shortly after development during a short, very cool summer season, probably within the last five years.

The iced firn and old lake ice units together constitute more than ninety percent of the "bedrock" exposed at the surface of the island. The pads of modern lake ice are superposed on the "bedrock" ice types.

Data collected suggest a progressive, though probably non-cyclic, sequence of development of surface forms on the island. This sequence is characterized by repeated inversion of relief. Specifically, during the course of the melt season, the ice units which have the highest albedo values and the most favorable crystal structures weather into topographic prominence. In order of decreasing relief, these are the modern lake ice which forms mesa-like features, the old lake ice which is expressed as narrow elongate ridges, and the iced firn which develops the inter-ridge valleys and lowlands. Inasmuch as rate of development of these features is dependent primarily upon intensity and character of the ablation season, attainment of maximum relief may require several seasons.

Because the modern lake ice bodies formed as topographic lows, their presence as topographic highs constitutes marked inversion of relief.

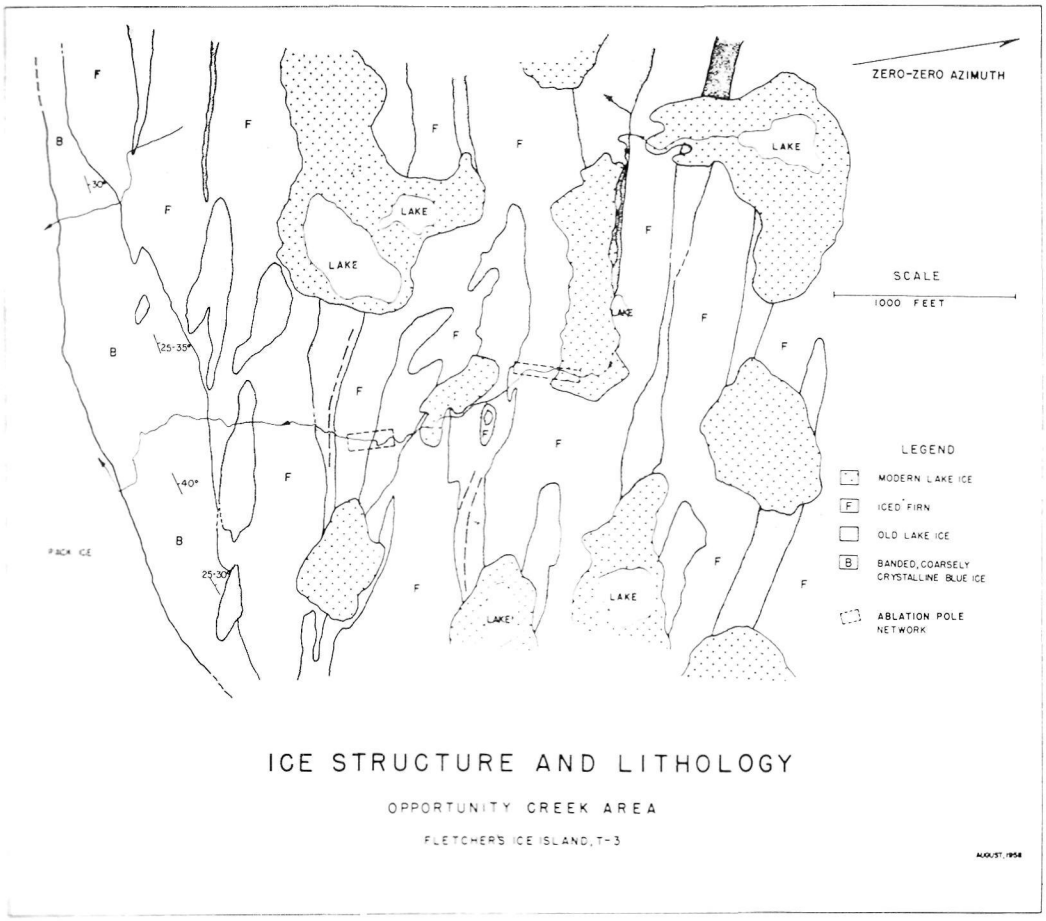


Figure 1.

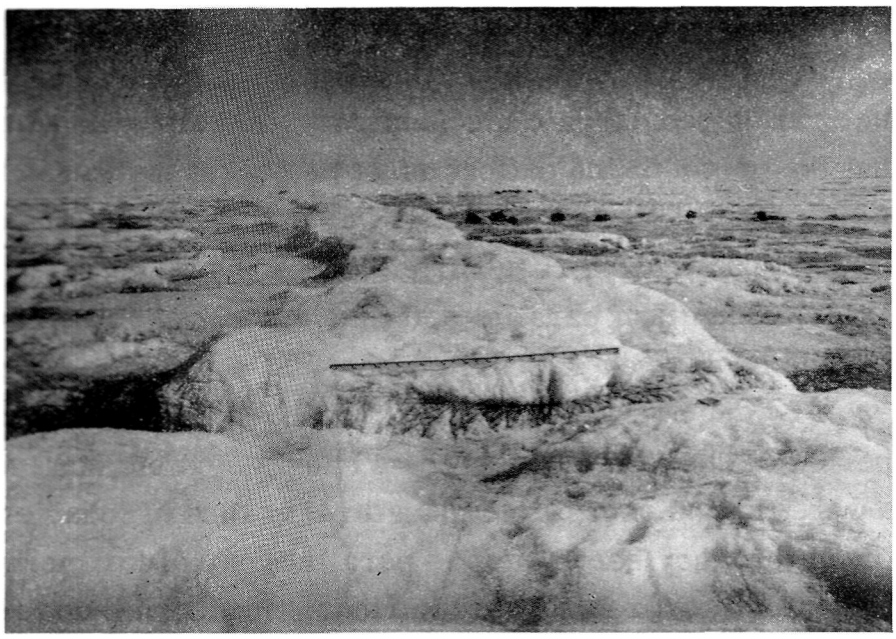


Figure 2. Example of elongate body of old lake ice. Note the topographic contrast between the ridge-forming old lake ice and the iced firn that underlies the adjacent lowland. Stadia rod is 13 feet long. Late August, 1958.

Their life as highs is of limited duration, however, because the protective pad of modern lake ice is eventually destroyed by thinning and undermining, probably after two or three seasons. The less reflective "bedrock" ice types are then exposed and the remnant of the high is quickly reduced by melting. This sequence can be reinitiated only when another short cool summer freezes large undrained lakes and produces new protective caps.

Because of the progressive downmelting of the surface, ridges of old lake ice are also destroyed after a few seasons. New ridges develop, however, as melting exhumes similar lenses buried deeper in the section. It is the linear pattern of these bodies of old lake ice which forms the structural grain of the island. The elongate modern lakes which are so typical of T-3 generally parallel and are controlled by this structural grain. Air photographs of the island taken during the melt season show the parallel lakes separated by relatively narrow linear ridges. These ridges are generally underlain by bodies of old lake ice. The inter-ridge depressions in which the lakes occur are developed primarily on iced firn. A similar relationship may obtain for the parallel lakes on the Ellesmere shelf.

Most of the previously proposed causes for lake orientation on the Ellesmere shelf and on its ice island offspring stressed currently operating structural or geomorphic mechanisms. G. Hattersley-Smith in 1957 held that the origin of the pattern must be sought instead in the conditions which prevailed when the shelf was building up. He proposed that modern inter-lake ridges result from the perpetuation, by channelized meltwater runoff, of parallel seif-like snow dunes present on the surface of the shelf when the current phase of degradation began. Several lines of evidence strongly support the existence of such dunes during the period of shelf buildup. In the writer's opinion, however, these dunes were the indirect rather than direct cause of today's structural control, in that they served as the parallel control for meltwater lakes which eventually froze and were buried by iced firn thus forming the bodies of old lake ice now exposed on T-3. The lensoid character of these bodies, the interfingering relationship of their edges to the enclosing iced firn, and their striking similarity to the overall

stratigraphic relations exhibited by channel fill deposits in terrestrial beds affords strong support for this origin Thus the parallel pattern of the structural control results from the original dune-controlled orientation of lakes during shelf buildup

Future surface morphology work on T-3 should stress an intensive study of the microclimatology and detailed albedo characteristics of a selected area representative of the various ice types and related surface forms present on the island.

OCEANOGRAPHIC SURVEY ON IGY DRIFT STATION "BRAVO" T-3

A. E. Collin, Fisheries Research Board, Canada

The 1958 summer oceanographic program for T-3 was planned as a continuation of the original IGY oceanographic survey. This survey included collection of water samples for the determination of salinity, temperature readings at standard depths, and determination of the organic phosphate content for the entire water column. In addition to these measurements, the 1958 summer plans included determination of dissolved oxygen, an investigation of the seasonal changes which take place in the water layer immediately below the ice, the installation of a Roberts radio current meter, a series of wire soundings, cores, bottom samples, and periodic plankton collections. Since the movement of T-3 is erratic and cannot be predicted on a daily basis, the oceanographic measurements were taken weekly. In this way, the chances of obtaining a suitable grid of observations for dynamic studies were increased, and more measurements within the surface layers were made available for a study of the seasonal pattern.

On several occasions samples were collected from ice cores taken both of T-3 ice and sea ice. The organic phosphate and dissolved oxygen content of these specimens were determined at the time of collection and the melt-water samples were preserved for salinity determination.

The measurements of organic phosphate, dissolved oxygen, and pH were conducted in the oceanographic laboratory on T-3, and the salinity samples were preserved in the normal Copenhagen type water bottles. A Klett-Sommerson colorimeter was used for the phosphate determinations, and the content of dissolved oxygen was determined by the Winkler method. The pH measurements were carried out on a model G Beckman pH meter.

The thermistor rig which was supplied by the Woods Hole Oceanographic Institute proved to be a most reliable instrument. On all occasions the apparatus functioned perfectly and produced reliable readings of temperature with depth. When being lowered through slush and brash ice the

thermistor was protected with a polyethelene cover which allowed free circulation and at the same time protected the thermistor from contact with the ice.

The oceanographic "station" was situated about 1-1/2 miles from the main camp about 100 yards off the edge of the ice island. Here a small Jamesway hut formed a shelter for the gasoline winch and the various pieces of equipment which were left at the "station" throughout the summer (Fig. 1).

A preliminary discussion of the oceanographic profiles is limited since the salinity data are not yet available; however, the temperature plots show several interesting characteristics. Temperatures taken at the surface of the water in the "icehole" are not reliable as the protection offered by the hut and the warmer air inside the shelter during the day caused a considerable variation in the surface water temperature.

Measurements taken at a depth of 5 meters below the water surface are indicative of water temperature slightly below the base of the ice, which at this position was 15 feet thick. The minimum temperature at this level was -1.71°C, recorded in late May. During the first week in June temperatures rose suddenly to above zero and continued to rise at a more gradual rate until a maximum of 0.47°C was reached in the middle of August. After this peak the temperature at 5 meters dropped quite uniformly to -1.30°C at the last observation on September 29. The warming of the water layer at the base of the ice in early June appears too early to be caused by increased island runoff. It is more probable that this temperature increase was caused by the daily use of the stove in the hydrographic shack.

Water temperatures at the bottom showed little or no change throughout the summer. At 1000 meters depth the bottom water temperature was between -0.09°C and -0.11°C. At 2000 meters, bottom temperature was -0.37°C.

The Atlantic water layer, which has been identified at all polar stations, was found at all T-3 stations. The boundaries, which are taken as the two zero degree isotherms since the salinity results are not available, remained quite constant during the summer at 270 and 1000 meters for the top and bottom respectively. The maximum temperature

recorded within the layer was 0.51° C at 600 meters and the lowest maximum was 0.40° C. In the one case where the depth of water was noticeably less than 1000 meters the Atlantic water formed the bottom layer. In this instance the temperature at a depth of 650 meters, within 20 meters of the bottom, was 0.17° C.

Recent Russian literature on the scientific results of the drifting station of 1950-1951 has described the occurrence of a "Pacific Interlayer" at a depth of 75 meters. This water is revealed by a sharp increase in temperature and salinity with a maximum temperature as high as -0.70° C and salinity of about 32 o/oo. Several T-3 stations show a slight increase in temperature at this depth but in no instance does the temperature approach that quoted from the Russian stations. In the eastern Beaufort Sea the temperature at 75 meters depth during the summer of 1958 was about -1.37° C.

Determinations of organic phosphate and dissolved oxygen were carried out at all except the first two stations. The phosphate results show that a distinct minimum develops at the 5 meter level as the thaw progresses and that there is a constant maximum at the 150 meter level. Throughout the summer the readings at a depth of 5 meters were typically zero or slightly above. At the bottom the average content was 0.9 μg-atoms/l. A maximum of about 3.0 μg-atoms/l was found to occur at 150 meters at all of the stations. The oxygen results show a somewhat similar relationship. As the summer progressed oxygen content at 5 meters increased to 10.0 ml/l in comparison to 7.8 ml/l recorded at the end of May. An oxygen minimum of 6.1 ml/l always occurred at 150 meters and the bottom content remained uniform at slightly over 6.4 ml/l.

The range of pH from surface to bottom was found to be approximately 6.6 to 8.1. The higher values always appeared between 30 and 75 meters depth; the minimum was invariably at the surface. A second minimum of about 7.6 was a characteristic feature at 150 meters.

During the summer, current measurements were attempted with several instruments, including a Roberts radio current meter, an Ekman meter, a Gurley current meter, and finally a drag-type meter. It was found that the Roberts meter, in addition to requiring almost constant attention, was not sensitive enough to record the water

Figure 1. Inside the oceanographic station, showing the thermistor cable, the Brush amplifier and recorder for the Roberts meter and the DC bridge and galvanometer for the thermistor apparatus. In the lower right is the "ice-hole".

movement. The Gurley meter, which was used throughout the summer, produced readings to a maximum depth of 200 feet; but the Ekman meter, even though it was lowered a number of times and left down for periods up to one hour, failed to record the relative current. Finally, in an effort to get some indication of water movement below 200 feet, a drag was constructed and readings were taken periodically during the latter part of the summer.

During the period May to October 1958 the drift of the island was in a general south-westerly direction from 80° 17' N, 114° 00' W, on May 3 to 78° 05' N, 122° 06' W on October 6 (Fig. 2). The average speed was on the order of 2 miles per day; however, during one period of strong winds, a speed of 8 miles per day was recorded.

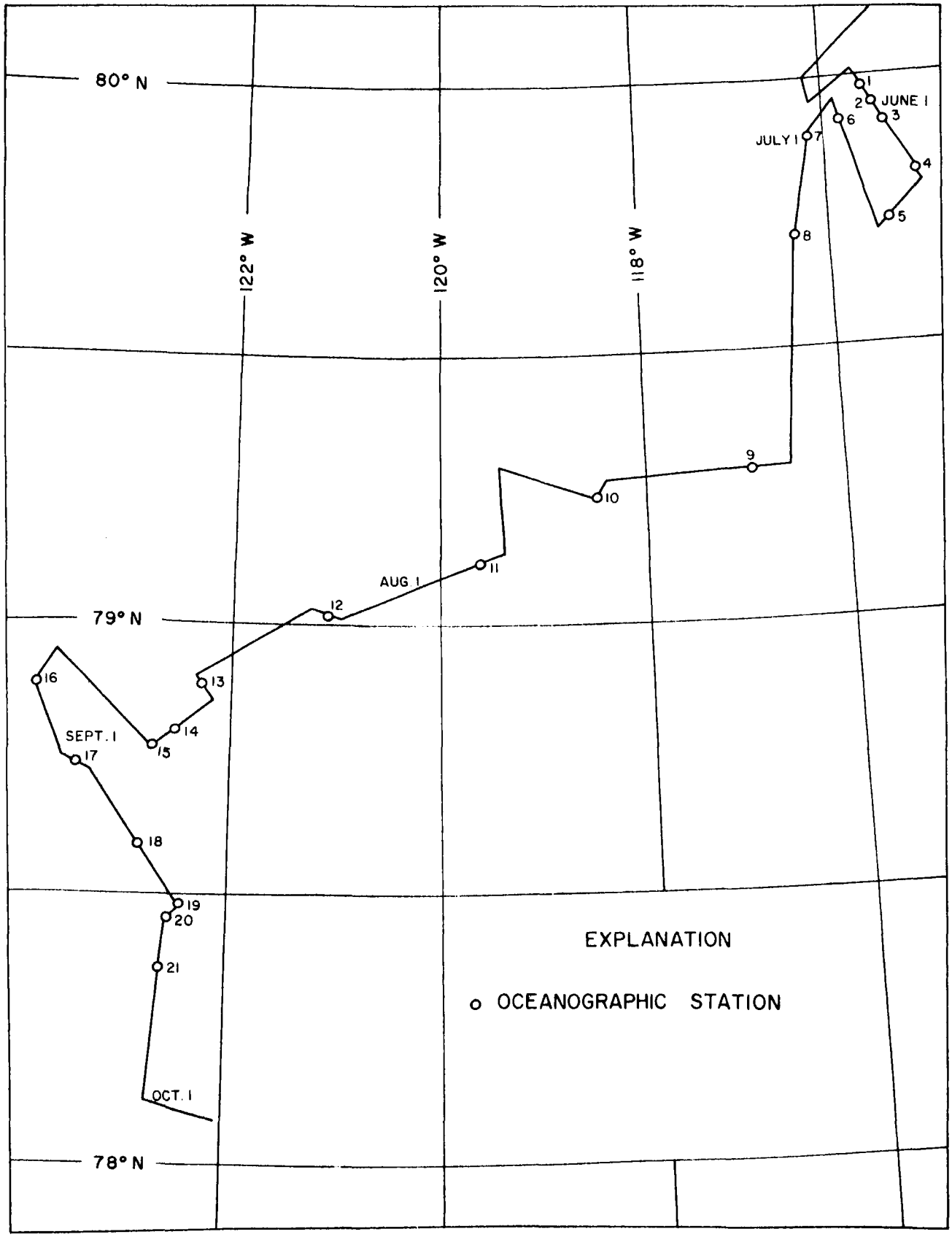


Figure 2. Map showing southwesterly drift of the island from May to October, 1958.

V. ARCTIC LAKE RESEARCH

PRELIMINARY RESULTS OF A STUDY OF A PERMANENTLY FROZEN LAKE IN GREENLAND

David F. Barnes, U. S. Geological Survey

During the summer of 1957 the Air Force Cambridge Research Center and Dartmouth College studied Angiussaq Lake, about 50 miles northeast of Thule, Greenland. This lake has maintained a 6- to 13-foot-thick ice cover for at least 10 years and is tentatively described as permanently frozen. However, a few more summers as warm as 1957 may melt the ice cover.

The lake-ice crystals were generally platelike in form, oriented with crystallographic axes horizontal, and ranged in size from about 0.2 to 100 cm^2 in horizontal cross section. The summer melting caused the breakdown of all crystal boundaries at the ice surface and the development of 0.2- to 1.0-cm diameter tubules that penetrated the entire ice thickness. Studies of ice strength by in-place cantilever beams indicate that the upper 2 feet of ice has almost no strength, but that the lower part of the ice sheet has about three-fourths the flexural strength of cold ice. The ice surface had a gently rolling relief of about 1 foot.

The lake also contained a floating tongue of glacial ice 2 miles long and more than 200 feet thick and four ice islands more than 40 feet thick. These thick ice bodies consisted of a central portion of granular, stratified ice and a bordering portion of very coarse-grained ice.

The water depth averaged about 250 feet with a 615-foot maximum. The water temperature was about 0.2°C at the surface and increased to about 0.4°C at its deepest point. Comparison with nearby lakes suggests that the 1900-foot elevation of the lake surface is not sufficient explanation for its permanently frozen condition. A favorable balance between the heat carried into the lake by inflowing streams and the total volume of lake water is required.

VI. GENERAL PAPERS

UTILIZATION OF ICE AND SNOW IN ARCTIC OPERATIONS

W. D. Kingery, M.I.T.

Limitations of ice and snow as engineering materials are related first to the engineering properties of these materials and second to the present state of development of processing techniques. The best natural product is pure lake ice, which has an average tensile strength of about 12 kg/cm^2 and a compressive strength of about 45 kg/cm^2. Design stresses must be much lower than these values since large variations occur between samples. In addition to its low strength, ice readily deforms with time under stresses as low as 2 to 3 kg/cm^2, so that it is unsuitable for bearing long-time loads. Other natural products, such as sea ice and compacted snow, have even poorer properties. For wide-scale utility of ice and snow as engineering materials, it is essential either to improve the material properties, or improve processing and use techniques, or both.

The large masses of ice required for practical uses as a construction material could conceivably be built up in many ways. Excavation techniques and fresh water flooding have been successfully demonstrated and fairly widely used. However, widespread utility of sea water solidification and effective methods for snow compaction have not been satisfactorily achieved; and techniques for extending the period of usefulness by controlling ablation with refrigeration and other techniques have not been thoroughly explored.

The overriding property development necessary to achieve practical utility of these materials is the improvement of strength and creep characteristics. Two possible approaches to developing improved properties are (a) dispersion hardening to improve creep properties, and (b) reinforcement to improve both strength and creep resistance. We have carried out crude preliminary tests of these methods by forming ice samples containing (a) 5% of well-dispersed kaolinite particles or (b) 8% fiberglass strands for reinforcement. As shown in Table 1, resulting properties are encouraging; further studies are clearly indicated.

TABLE 1. EFFECT OF ADDITIVES ON STRENGTH PROPERTIES OF ICE AT -15° C

Material	Average Modulus of Rupture (kg/cm^2)	Relative Deformation after 24 hours
Ice	18	25
Ice containing 5% kaolin	23.5	<1
Ice containing 8% fiberglass	100	<1

Process developments which are of greatest potential usefulness are (a) sea-water solidification, (b) snow densification, and (c) ablation control. The main problem in sea-water solidification is the salt content which leads to the presence of residual brine at low temperatures as shown in Fig. 1. There is still 15% liquid present at -20° C. Elimination of the concentrated brine left after solidification would be possible in an alternate freeze-cool-freeze cycle such as shown in Fig. 2. Calculations indicate that such a process deserves further investigations. Densification of snow must be approached from the point of view that it is a time-dependent process. Available data (Fig. 3) show a time dependence, $(\frac{\Delta L}{L_o}) \sim t^{2/5}$, consistent with diffusional processes being rate-controlling (Kingery and Berg, J. Appl. Phys., 55, 1201 (1955)). This suggests that the basic problem is to obtain micron-sized particles; an approach to studies of snow comminution and subsequent densification on this basis is worthy of further study. An analytical study of potential methods of ablation control is essential as a prerequisite to engineering or experimental studies.

In summary, while the present utility of ice and snow as engineering materials is very limited, its potential utility is great. Further studies of various approaches to developing methods of using this widely available material appear promising.

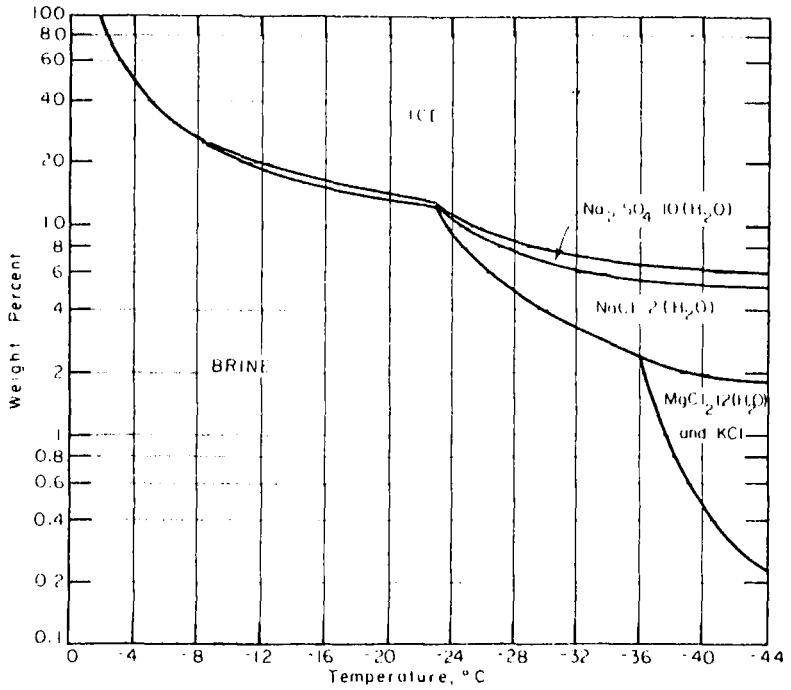


Figure 1. Phases present on cooling sea water (after D. L. Anderson, from data of Nelson and Thompson, J. Marine Res., 13, 166 (1954)).

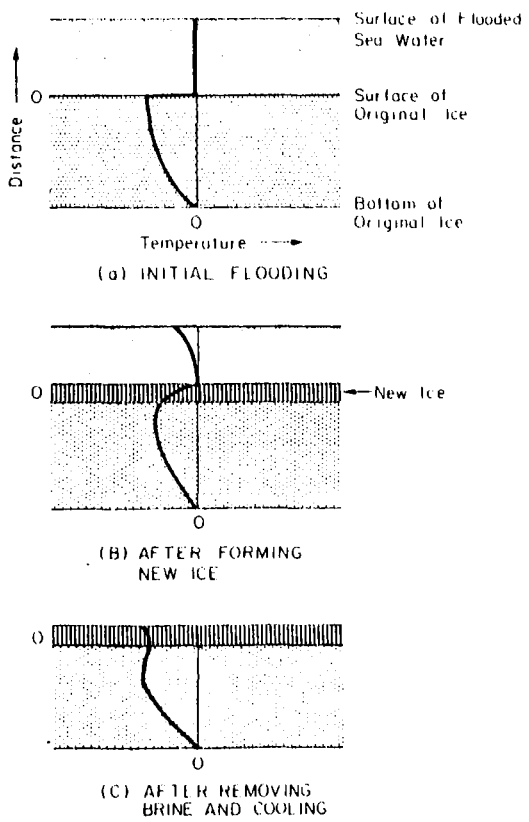


Figure 2. Flooding, freezing and cooling cycle proposed for sea-water solidification.

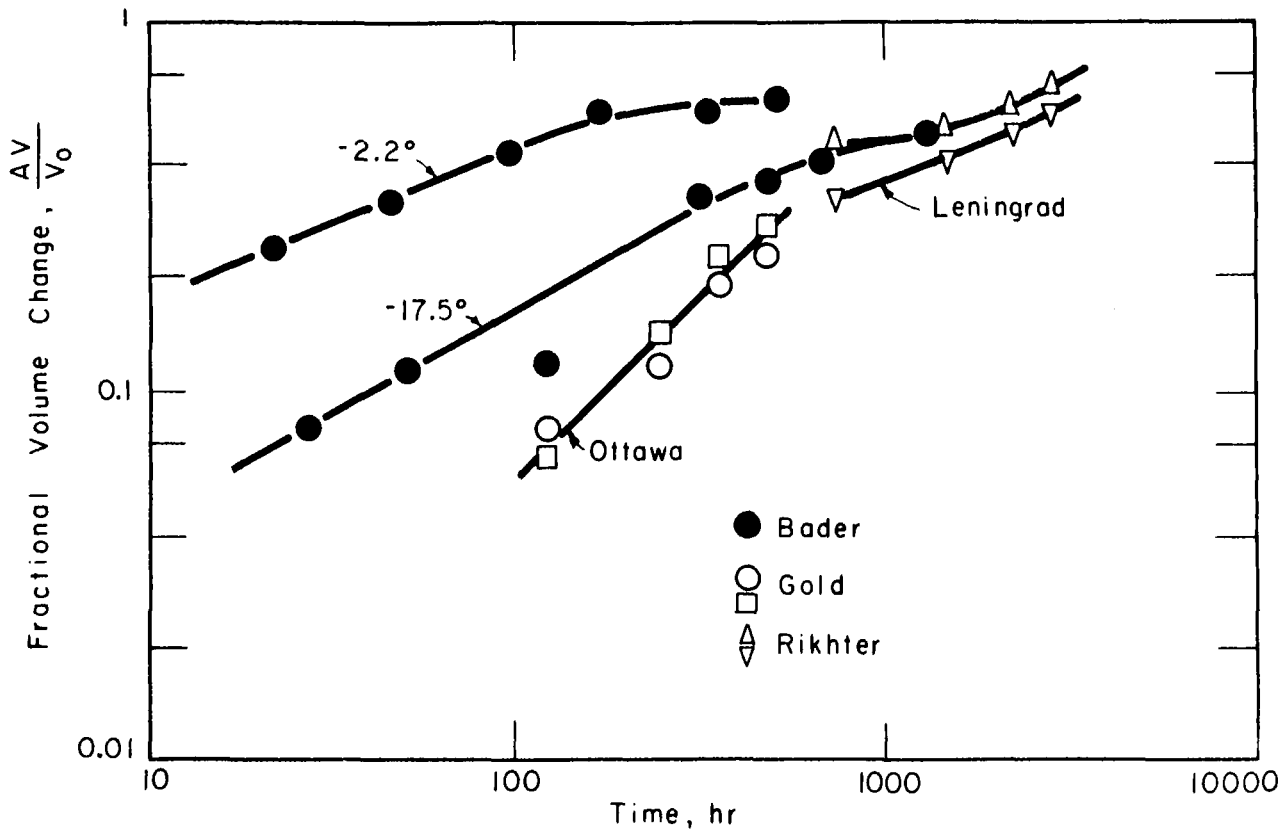


Figure 3. Densification rate of various snow samples as reported in the literature. Only data of Bader is for isothermal conditions.

THE SEA ICE PHYSICS PROJECT
1954-1959

W. F. Weeks, St. Louis University

The Sea Ice Physics project was organized in 1954 by the Air Force Cambridge Research Center (AFCRC) at the request of Hq. Northeast Air Command to study the physical properties, growth, and bearing capacity of sea ice. The agencies participating in the scientific part of the project were AFCRC, the Navy Hydrographic Office (NHO) and the Snow, Ice and Permafrost Research Establishment (SIPRE). Field work was initiated in January, 1955, at Hopedale, Labrador by AFCRC and NHO. During this season, the project personnel were at a disadvantage because of the "crash" nature of the project, logistic problems, and their inexperience in studying the peculiarities of sea ice. However, a small amount of good seismic, oceanographic, and micrometeorological data were collected. The second winter at Hopedale, SIPRE joined in active participation in the studies. Test procedures and field equipment were revised, and the general research program was considerably expanded.

During the winter of 1956-57 the project field site was moved to Thule, Greenland, in order to take advantage of a more clearly established supply route and readily available heavy equipment. Thule also offered the opportunity to study a thick sheet of sea ice under conditions more typical to the Arctic. In 1957-58 the field program was greatly curtailed because of losses of scientific personnel and changes at Thule. There have been, as yet, no field investigations during the 1958-59 field season.

The main contributions of the project are:

(a) measurements of the strength of sea ice under carefully determined conditions;

(b) determination of a semi-quantitative picture of the geometry of the inter- and intra-crystalline structure of sea ice;

(c) maintenance of a continuous series of measurements of the meteorological conditions, ice salinity, temperature profile, and growth rate;

(d) a phase diagram for the temperature dependence of the brine volume and presence of solid salts;

(e) a theory for the variation of the strength of warm sea ice as a function of temperature and salinity;

(f) theoretical and experimental values for the variation of the thermal conductivity of sea ice as a function of temperature and salinity;

(g) seismic methods of determining ice thickness and elastic characteristics;

(h) knowledge of the difficulty of predicting ice growth rates by empirical methods;

(i) statistical studies of the lateral variation of the salinity of different types of young sea ice; and

(j) an increase in the knowledge of problems associated with the movement of vehicles and aircraft across sea ice under marginal conditions.

Operational problems relating to the physical characteristics of sea ice usually involve the following aspects:

(a) what load can be placed on an ice sheet of a given history at a specific temperature and how long can it safely remain in place; and

(b) when will the ice at a presently inaccessible area be of the strength required in (a)?

To answer these questions, it will be necessary to:

(a) accurately predict freeze-up dates and ice growth rates from meteorological data;

(b) know the structure of the ice and the amount of brine incorporated into the ice as a function of the salinity of the sea water and the ice growth rate;

(c) know the physical properties of ices of different structures, compositions, and histories at any given temperature; and

(d) be able to apply these physical properties via suitable equations to calculate a margin of safety for a given operation.

GEOPHYSICAL STUDIES IN PERMAFROST

Max Brewer, ARL, Point Barrow

We have been fortunate that our permafrost studies have been a long term project; thus we have been able to plan ahead for studies that would otherwise have been impossible. The project was originally set up in 1949 to measure heat flow in dry holes drilled in Petroleum Reserve #4. Readings were taken for some years afterward, and thus we obtained the rates of cooling and the temperature of the earth prior to drilling the holes. Work has also been carried on at Point Barrow, Umiat, Fairbanks, and Glenallen; in addition, we have furnished thermistor cables for work at Resolute Bay, Cornwallis Island, and the Juneau Ice Field.

Later the project emphasis changed, and the engineering aspects of permafrost, the effects of water bodies on permafrost temperatures, and several other problems of similar nature were taken up. We have used the method of studying type localities intensively so that we could deduce general principles, with the thought that these principles could be applied elsewhere.

Many different types of instrumentation were used. The thermal cables were mostly supplied with thermistors, although we used some old copper resistance coils left over from the late 1930's or early 1940's. All can be used successfully if their peculiarities are understood.

The studies were undertaken with emphasis on temperature gradients from the surface down; that is, the problem is one of conduction of heat. We have generally stayed away from measurements above the surface, which are also important, because they would complicate the problem tremendously. We have not emphasized, but are aware that we deal with, physical properties; oftentimes we have not taken into consideration how they got where they are. If we are dealing with sand, for example, we are not necessarily interested in the origin of the sand, but in what the properties of the sand are. We have studied

the effects of topography of permafrost, the effects of lakes on temperature of the underlying materials, the effects of rivers and the effect of the Arctic Ocean (at least in the vicinity of Point Barrow) on the subbottom temperature profiles. We have measured the temperature regimes through fresh ice, sea ice, and ice on brackish lagoons. In connection with these studies, we have worked with the rates of formation of ice in different environments and have compared the physical measurements with the rates of formation to be expected from the thermal gradient through ice. More practical studies have included the effects of engineering structures on permafrost, such as airfields, bridges, highways, and buildings and other structures.

In general, we have tried to isolate the factors affecting temperatures in permafrost. The problem contains at least six or seven unknowns, so we have chosen areas where one could eliminate all the unknowns except one and work on that one problem. For instance, we study the effect of water content of the soil on the permafrost. Apparently, after the effect of the surface, water content is of primary importance in determining effects of permafrost on engineering structures. Effects of precipitation, transpiration, and respiration have not been tackled, although we know these are important.

The length of time snow and ice cover remain on the ground radically affects the mean annual temperature underground. It has been hoped for many years that we could take air temperatures and from them interpret the ground temperatures. In future studies we may be able to derive a conversion between air and ground temperatures, but only when the problems are better understood, and only if such items as topography can be worked into the formula.

THERMAL STUDIES IN ARCTIC ICE AND PERMAFROST

A. H. Lachenbruch, U. S. Geological Survey

The objectives of the program are to measure and interpret temperatures in permafrost and to formulate the general laws controlling thermal phenomena in permafrost by combining field measurements and theory. We try to explain what we observe in the accumulated data in terms of the physics of heat conduction and then to formulate laws that have some measure of applicability to new areas.

The first thing needed in such a program is reliable and intensive data from a type locality. The colder areas are best because there are fewer complications.

Permafrost is essentially a geothermal phenomenon. We start with the fact that heat flows from the interior of the earth at a relatively constant rate, and superimpose on its effect that of seasonal fluctuations in surface temperature. This is the steady uncomplicated basic picture, the background against which we work. Most thermal problems in permafrost can be treated as anomalies, or departures from this basic thermal model.

To take an example, studies of the Arctic Ocean and tundra lakes show that the mean annual temperature of the bottom sediments is relatively constant in time and space. Using this fact of observation we can solve a mathematical problem to get the temperature anomaly in permafrost caused by bodies of water. The solution of such a problem gives a means of predicting the distribution of permafrost in the vicinity of a lake, ocean, or river with a minimum of observational information. From a thermal point of view the foundation of a heated building behaves very much like a lake, and the same theory applies. Inasmuch as the thermal anomaly depends not only on the temperature and shape of the body of water but also on its age, thermal methods may be applied to investigate the age of lakes and transgression or regression of ocean shorelines during the last few thousand years. Similarly the same solution gives a means of predicting the change with time in size and shape

105 009

of the thawed basin beneath a heated building. Several other fundamental theoretical problems have wide application to the interpretation of thermal regimes in permafrost, but this single example suffices to illustrate the generality of the method.

Two climatic parameters are very important in this work: (1) the amplitude of the temperature variation at the surface of the earth, and (2) the mean annual temperature at the ground surface. Continuous observations are needed to get these parameters, and although some good continuous recording instruments are available, they must be serviced on a weekly basis. Hence our data from the Arctic must be obtained at the sparsely distributed manned bases. If a device could be obtained that would record temperatures for a year unattended, we could get the two parameters necessary for good interpretation of the climatic data in relation to permafrost in remote areas.

ARCTIC APPLICATIONS RESEARCH

C. E. Molineux, AFCRC

The function of the Applications Branch of this Laboratory is to seek out, evaluate, apply, and present geophysical information, techniques, and instrumentation for the solution of design, development, and particularly operational problems of the Air Force. This function may involve routine compilation of available information, but more often stresses the support and application of research efforts

Illustrations of the first category are publications for Air Force use. These have recently included: (1) Sections of the GRD "Handbook of Geophysics for Air Force Designer", presenting comprehensive data on the properties and various parameters (particularly bearing strength) of ice, snow, and soil; (2) an illustrated brochure on the arctic research activities of the Laboratory; (3) an Air Force Survey in Geophysics publication on forecasting soil moisture and strength from climatic data; and (4) a comprehensive bibliography of arctic research reports and seminar papers authored by our personnel. Now in active preparation are a history and technical summary of the research activities on T-3; and an AFSG presenting research results, engineering standards, and operational recommendations for establishment and use of natural sea-ice runways.

The second category comprises both in-house and contractual research, aimed at enlarging the capability of aircraft operations on all types of surfaces. Ice engineering or laboratory and scale-model experiments will supplement and enlarge our field investigations of ice elasticity and strength, vibration and seismic techniques, crystal and salinity studies, rate and conditions of growth, and potentials of flooding for increasing thickness and smoothing the ice surface. Such work will likely be conducted at the Climatic Hangar at Eglin AFB.

Airborne determination of ice properties appears feasible, and plans have been made for further development and field testing of a radiometer for determining ice temperatures, albedo, and possibly

thickness. Several airborne radar and electromagnetic techniques are being evaluated for determining the thickness of large masses of freshwater ice such as glaciers, icebergs and frozen lakes.

The air-droppable seismograph for immediate determination of ice thickness was previously developed in this Laboratory. Its refinement will be usable by any reconnaissance aircraft through miniaturization and an improved recording system.

Airborne determination of snow properties by a refined aerial penetrometer will indicate snow thickness and moisture content in addition to its present capability to indicate snow hardness. The prototype aerial penetrometer used for airborne determination of soil hardness is currently being modified to meet a Tactical Air Command requirement for wartime reconnaissance of airstrips.

A unique and promising method of terrain compaction and stabilization by detonation of a blanket of foamed explosive is being initiated. Its use for airstrip preparation, snow compaction, and smoothing of ice surfaces is readily apparent, and a feasibility study may indicate other uses for the impact and heat forces generated.

Lastly, the Applications Branch has been enlisted in forthcoming research on icing and wind loads on communications facilities in the Arctic, and expects to perform controlled experiments of icing conditions on wires and model antenna structures in connection with ice engineering studies.

THE C-130 AS A SUPPORT AIRCRAFT

Captain T. D. N. Douthit, USAF

The Air Force "Ski-130" Hercules (Fig. 1) has broken all known records by lifting 124,000 pounds from a frozen lake near Bemidji, Minnesota. Takeoff run was only 1,450 feet using JATO bottles for jet assist. Powered by four Allison T-56 turbines totaling 15,000 horsepower, the huge craft averages 300 knots true airspeed up to 35,000 feet altitude. It is completely air-conditioned and pressurized, and utilizes booster type controls for ease of flying. A ski-wheel configuration is employed,and the change from skis to wheels may be made automatically while the plane is on the ground. The main skis weigh 2000 pounds each and have a ground clearance of about eight inches when retracted. The tires do not extend through the skis when the skis are down with the gear retracted.

The nose ski is steerable, and in addition, differential power may be used for directional control while taxiing. Fully reversible props with 40% power in reverse are available for shorter stops. The Hercules is capable of landing and stopping within 1500 ft with a maximum payload of 35,000 pounds. Airborne, it climbs 2450 feet per minute, fully loaded.

Range is a factor of fuel versus payload. The aircraft is capable of over 2000 miles with a 15,000 pound payload. The attached chart (Fig. 2) gives distances and flying time for various routes in the Arctic. Flying time was computed against a 40-knot headwind in each case.

A unique press button cargo loading and unloading feature is to be incorporated on the aircraft. In this system a hydraulically-operated tail gate is lowered, leaving an aft opening that measures 9 feet by 10 feet. A winch cable is attached to loaded tandem hitched pallets. When a button is pressed, up to 35,000 pounds of cargo may be loaded or unloaded in forty seconds. While not a panacea for all problems of arctic flying, the "Ski-130" beyond a doubt is the most advanced and most suitable aircraft available today for the job and will be for many years in the future.

Figure 1.

LOCKHEED C-130B ON NEAC ROUTE SYSTEM

40 Knot Headwind

Route	Distance	Payload	Take-Off Weight	Cruise Speed	Flight Time
	N. Miles	Pounds	Pounds	Knots	Hours
Dover - Harmon	964	36,800	126,600	299	4.3
Dover - Goose	1109	36,800	129,100	299	4.9
Harmon - Goose	300	36,800	116,800	297	1.6
Goose - Narsarsuak	670	36,800	122,500	297	3.0
Goose - Frobisher	885	36,800	125,700	298	3.8
Goose - Sonderstrom	860	36,800	125,400	298	3.7
Goose - Thule	1453	36,800	134,400	300	6.0
Goose - Nord	1910	30,500	135,000	299	7.8
Goose - Alert	1750	32,500	135,000	300	7.1
Narsarsuak - Sonderstrom	385	36,800	117,500	297	1.9
Narsarsuak - Alert	1310	36,800	132,600	300	5.5
Narsarsuak - Thule	1040	36,800	127,600	299	4.5
Narsarsuak - Nord	1350	36,800	133,100	300	5.6
Narsarsuak - Frobisher	663	36,800	122,400	297	3.0
Sonderstrom - Frobisher	692	36,800	122,750	297	3.1
Sonderstrom - Alert	955	36,800	126,500	299	4.2
Sonderstrom - Thule	660	36,800	122,400	297	3.0
Harmon - Narsarsuak	890	36,800	125,700	298	3.8
Harmon - Sonderstrom	872	36,800	125,500	298	3.7
Harmon - Frobisher	882	36,800	125,600	298	3.8
Harmon - Alert	2070	28,100	135,000	298	8.5
Harmon - Thule	1720	33,300	135,000	300	7.1
Harmon - Nord	2160	27,000	135,000	298	8.8
Sonderstrom - Nord	1050	36,800	127,700	299	4.6
Thule - Alert	375	36,800	117,400	297	1.8
Thule - Nord	680	36,800	122,600	297	3.0
Alert - Nord	410	36,800	117,800	297	2.0
Frobisher - Thule	780	36,800	123,700	297	3.4
Frobisher - Nord	1360	36,800	133,200	300	5.6
Frobisher - Alert	1150	36,800	129,600	299	5.0

Rules:

(1) Long range cruise at 25,000 feet.
(2) 40 knot headwind for all routes.
(3) 6500 pounds of reserve fuel on all routes.
(4) Max. T. O. Wt. - 135,000 lb.
(5) Max. zero fuel wt. - 104,216
(6) Equipped Weight Empty - 67,366
(7) Max. Fuel - 6900 U. S. Gallons.

Figure 2.

USE OF LIGHTER-THAN-AIR CRAFT IN THE ARCTIC

Captain H. B. Van Gorder, USN

On 8 August 1950, the first Navy airship crossed the Arctic Circle. The next day it circled Fletcher's Ice Island, T-3, and dropped a sack of mail to the scientists living on the island. Prior to this first penetration of the Polar area by an American airship, the author was asked to undertake a study of the possibility of using airships as vehicles in arctic research by the Office of Naval Research. Such studies had previously been shelved because of the supposedly bad weather in the far north, but more recent studies showed that the weather in the summer months is better than that in the United States.

If one is to explore the Arctic and look at the terrain, there is nothing better than a flight in an airship at an altitude of about 500 feet and with an airspeed of about 40 knots; it gives the viewer lots of time. The airship is an ideal platform for observation, photography, and as a vehicle for special instruments.

The airship used on this arctic flight was a ZPG-2, 348 feet long, with a capacity of one million cubic feet of helium (Fig. 1). The route took the aircraft to Fort Churchill, Resolute Bay, and out over the arctic ice pack. The total distance flown was 6885 miles, and the airship was airborne for a total of 168 hours.

On the trip, we took off from Resolute with the idea of spending about 30 to 40 hours cruising over the pack. After cruising out to T-3, we had about 38 hours of fuel left aboard, and, since the operating conditions at Resolute Bay left a lot to be desired, we decided to overfly Resolute Bay and go straight back to Churchill. We felt the mission had been accomplished, so we did this and thus eliminated refueling out of 50 gallon drums at Resolute Bay.

An airship requires only two additions to heavier-than-air operating facilities: (1) either a stick mast (which is anchored in place and to which the aircraft is walked by the ground crew) or a mobile mast (which can be rolled up to the ship), and (2) a supply of helium. A

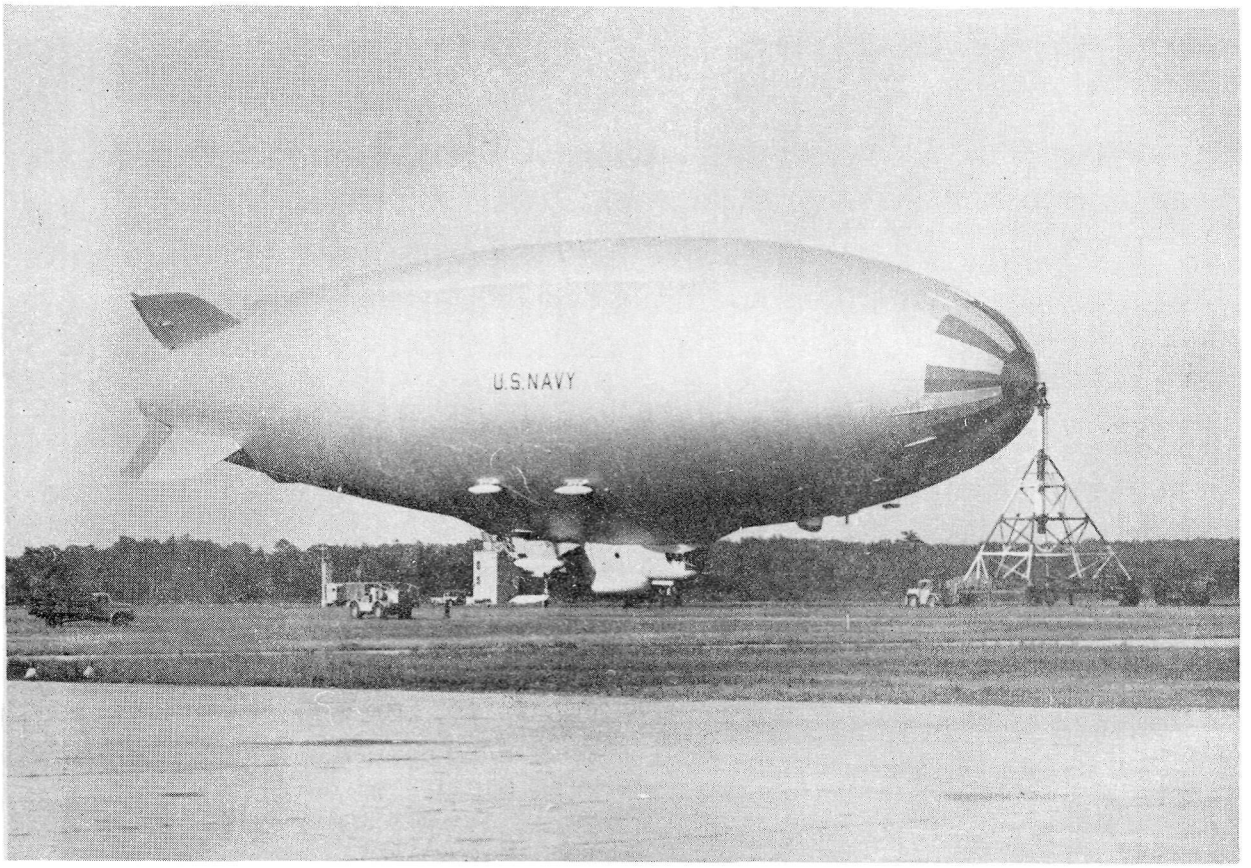


Figure 1. Airship ZPG-2, BuNo 126719, used on 1958 Arctic flight.

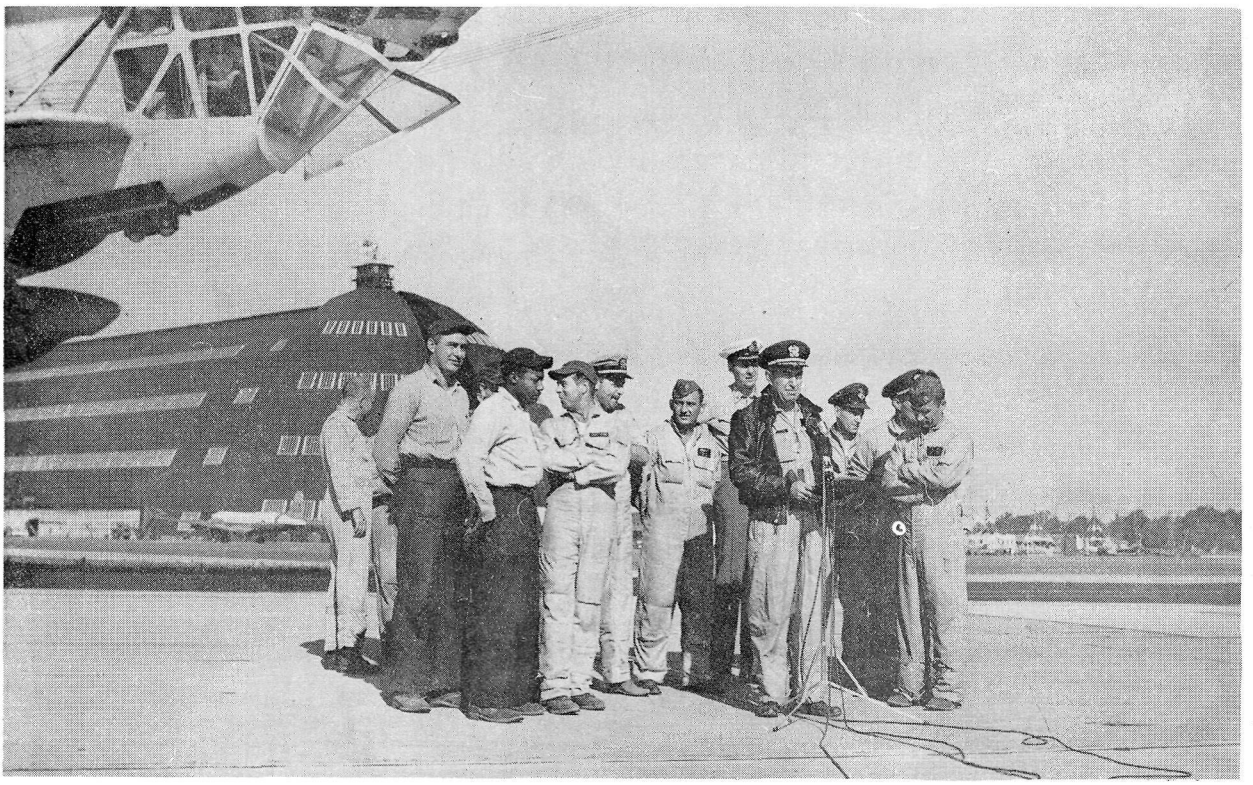


Figure 2. Captain H. B. Van Gorder and crew of ZPG-2 126719.

minimum number of personnel are needed to land and take off the ship. Normally, we need about 20 to 25 people, besides the regular airship crew, to help land and moor the airship.

The ZPG has an endurance, in the summer and in the Arctic, of about 75 hours in the air with full fuel capacity. Given a 40 knot airspeed and no wind, it has a radius of action of about 1500 miles from its base. The load carrying capacity of the airship under these conditions is about 4000 pounds of additional cargo, which is restricted to an area of 350 cubic feet. For shorter flights, of course, we can carry additional weight in the form of useful load, but the cubage restrictions still apply.

The ZSG is a smaller airship with a capacity of 600,000 cubic feet of helium, and is also ideal for arctic operations. The ZSG is better than the ZPG because of greater maneuverability of the former and its ability to land and take off in shorter, unprepared areas. The ZSG has 40 hours' endurance and a range of 800 miles with full fuel load, and can carry 4500 pounds of payload in an area of 200 cubic feet. The ZPG requires a relatively smooth area about 1500 feet long by about 150' wide to land and take off with the degree of safety required. Without ground handling personnel, the smaller ship can land in a circle about 300 feet in diameter under average wind conditions of 10-20 knots or less. The wind should be steady and some ceiling is required.

The airship has a great capability for accurate navigation. This summer we used the APN 77, a Doppler type navigation system, which gives an automatic drift at all times; it is an accurate instrument and was tested satisfactorily. Of course, we use standard navigational aids as well. We were fortunate to have Wing Commander Keith Greenaway of the Royal Canadian Air Force, probably the world's best navigator, with us on this trip.

The smaller airship, the ZSG, is more versatile, more maneuverable, and can set down in smaller unprepared areas. Fog doesn't bother us too much. Both ships have winch and cable equipment for lowering and raising equipment and personnel. This involves airship hovering, and is a safe maneuver, but it is not ordinarily done unless we can't put the ship down on the ice. We are now working on an idea for landing the ship that will be better for ice and snow conditions. At

present it always vanes into the wind on its single landing wheel. We can't use a ski, of course, because it would catch on obstacles, but a promising development is a sort of large aluminum saucer, somewhat like the newer types of children's sleds.

The Naval Air Development Unit has a continuing project to conduct operations in the Arctic. However, the Office of Naval Research does not have much money for this program, so if it is desirable to operate airships in the Arctic, somebody must have the requirement and the money to back up the requirement. One large and one small airship, for a period of three months, would cost about $100,000. This figure includes personnel expenses, fuel, helium, and transportation of masts and helium. Instead of using the light aircraft at T-3, as was proposed earlier in the session, why not use a smaller airship, not based at Resolute Bay or some other base near the Arctic Ocean, but right on T-3? This airship could then take people and a small amount of equipment out onto the pack for minute observations.

[A number of questions were asked from the floor; the following is a summary of that material.]

Excessively high winds (which are not prevalent in the area) of about 70-80 knots, would prevent safe mooring and unmooring. We need winds below 35 knots for general work; in general, winds should be less than 50 knots for landings in the area where the airship is based.

The design ceiling of the airship is 10,000 feet under standard atmospheric conditions. We may not be able to use it over the Ice Cap in Greenland except during certain periods.

Icing does not present the problem it does in airplanes, except on the propellers. We do get some problems with ice on the control surfaces. We can do as well as airplanes in most circumstances unless we pick up too much weight on the envelope.

The fuel consumption on long northern flights would be about 40 gallons per hour for the larger airship. The smaller airship uses about 25 gallons per hour.

The amount of helium used depends on the amount of flying done. To set down on the ice pack, for instance, we must valve off some helium. We estimate that we would need about 100,000 cubic feet of

helium for a summer operation — at least that is the amount we want on hand at the beginning of the operation. We keep the helium in helium trailers that contain about 30,000 cubic feet of helium and can be carried in a C-124. We would need three of these trailers for a summer's work.

The normal crew of the ZPG, the larger airship, is about 12-14 (Fig. 2). We carried 19 on the trip to T-3. On the smaller airship, we have a crew of about 8.

To operate only airships from a particular base, we need extra people on the ground to help moor and unmoor the airships. For the smaller airship we need an extra 20 people; for the larger airship we need about 35 extra people. To operate the large airship, we need about 30 people; this includes the crew and maintenance men. For two airships, we would require a total complement of 40 to 50 people. If we flew the smaller airship from T-3, we would need room at T-3 for about 15 to 20 Navy personnel; and at the same time we should have to enlist the aid of all the other scientists at T-3 for landings and takeoffs.

The cargo space is in one rather large area, and we could take a fairly large piece of equipment in the aft station. We also could sling equipment beneath the airship in a cargo sling, just as we tow sonar birds in ASW work.

MILITARY SIGNIFICANCE OF ICE-FREE LAND IN EAST GREENLAND

Colonel Bernt Balchen, USAF (Ret.)

The purpose of this talk is to point out some areas of ice-free land in east Greenland that are valuable to the Air Force for unprepared air-field sites, electronics installations, or that should be studied in the light of future weapon system concepts. The areas concerned must be studied for various factors that bear on their usability, but ease of accessibility is one of the important factors. Ground and sea access are vital, and of course the airlift will always be with us. Although I have been looking over this area for many years, always with the thought of military use in mind, scientists will still have to go in on the ground and make detailed observations.

From 1941 on we patrolled the east coast from BW8, and stations were found every year. As a result of our interest in this area, we made a study of the limited air operations carried out along this coast from 1932 to 1941. In 1933-1934, the Norwegian Polar Institute made some maps of the Mackenzie Bay area from aerial photos; they flew both a Lockheed Vega and DeHaviland Moth on wheels from the flats in the vicinity and reported no difficulty whatsoever in landing and taking off. In 1941 and 1942 several landings were made on the Scoresby Peninsula, both on the gravel terraces and on the dry permafrost areas. In 1942, Lt. Pritchard of the Coast Guard landed a Loening amphibian on wheels. I landed a PBY5A on wheels on the beach in the same year. I also landed a B17 in the same general area.

The development of natural landing strips is very important and Jameson Land offers some of the best facilities for ice-free air installations in Greenland. There are good gravel flats on the west side of Jameson Land near Hurry Fjord. The general area around Mackenzie Bay is well worth investigation; this includes the beaches around Loch Fine. A good site is to be found at Revet on the northwest side of Clavering Island. Other areas on the north side of Jameson Land are worthwhile. A gravel flat at Mesters Vig has been developed into a

small strip, and there are many areas to the south that bear investigating.

Many spots for unprepared airfields could probably be located on Hochstetters Foreland and on Shannon Island. Shannon Island is on the northern borderline of waterborne transportation. In Germania Land, the only place worth looking at is on Store Koldewey Island, near the northern end.

A survey of the east coast of Greenland could most logically be carried out with a small ice-navigating vessel that could carry a helicopter on board, and then go in as close as possible to the coastline. From there one could conduct flights from the deck with the helicopter. Such a ship could make a survey from Scoresbysund up to Germania Land.

A need at the present is for a chain of electronic sites in different areas. They can be put on highland areas that can be reached from the Ice Cap by tractor trains, in contrast to the airfield sites which are on the Lowlands. They can also be built and supplied by personnel in ski-C-130's, which have tremendous potential. The best areas for such larger installations are nunataks; some have crevasse-free approaches. Cecelia Nunatak is a good example of a large mesa-like nunatak, where, in addition, it would take very little to make a good landing facility.

Specialized equipment is needed for work in the Arctic. Today the tools are better than ever before, for example, the ski-wheel C-130, which can get the needed equipment to the spot where it is needed on frozen lakes, frozen rivers, and unprepared strips.

Aircrews should have an opportunity to assess those areas where unprepared strips are found. I would take a look at many of these areas from low level and without hesitation come in and land with a C-130 -- it can take a lot of bumps. Then a ground party should come in early enough to assess the thaw cycle. It is true that we will need experienced air crews and expert ground assessors. For instance, frozen leads are nice and smooth, and can be seen easily from the air -- they are tempting but dangerous. Prior to the establishment of T-3 one crew set up camp on a lead; the camp lasted less than twenty minutes when the ice started to move.

As to equipment, tents and present prefabricated huts are not too good. Probably some sort of trailer should be set up in the factory, perhaps packed in some sort of container so that it could be set up in an aircraft, flown to the spot, rolled out, and be ready for business. A similar principle should be applied to food, thus resulting in less wastage. To stage an operation like this calls for a specially trained organization, and after much work in the area the recurring experience would be at a maximum. One could then do more work in any one field season, and more and more work each year.

The Terrestrial Sciences Laboratory has a program that should go on for years and years. No matter how many ICBM's are produced, this kind of work in the Arctic must and will go on for years, because manned aircraft will be here for many years to come.

LIST OF GRD RESEARCH NOTES

1. Contributions to Stratospheric Meteorology, P. Antanaitis, T. R. Borden, Jr., R. A. Craig, W. S. Hering, H. S. Muench, H. A. Salmela, edited by George Ohring, August 1958.

2. A Bibliography of the Electrically Exploded Wire Phenomenon, by W. G. Chace, November 1958.

3. Venting of Hot Gases Through Temperature Inversions, by M. A. Estoque, December 1958.

4. Some Characteristics of Turbulence at High Altitudes, by M. A. Estoque, December 1958.

5. The Temperature of an Object Above the Earth's Atmosphere, Marden H. Seavey, March 1959.

6. The Rotor Flow in the Lee of Mountains, Joachim Kuettner, January 1959.

7. The Effect of Sampler Spacing on Basic Analyses of Concentration Data, Duane A. Haugen, January 1959.

8. Natural Aerosols and Nuclear Debris Studies, Progress Report I, P. J. Drevinsky, C. E. Junge, I. H. Blifford, Jr., M. I. Kalkstein, E. A. Martell, September 1958.

9. Observations on Nickel-Bearing Cosmic Dust Collected in the Stratosphere, Herman Yagoda, March 1959.

10. Radioactive Aggregates in the Stratosphere, Herman Yagoda, March 1959.

11. Comments on the Ephemerides and Constants for a Total Eclipse of the Sun, R. C. Cameron and E. R. Dyer. (to be published)

12. Numerical Experiments in Forecasting Air and Soil Temperature Profiles, D. W. Stevens. (to be published)

13. Some Notes on the Correlation Coefficient, S.M. Silverman. (to be published)

14. Proceedings of Military Geodesy Seminar, December 1958, Air Force Cambridge Research Center, (U), edited by O. W. Williams, April 1959. SECRET REPORT